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SPIRAL NEBULA IN URSA MAJOR, KNOWN AS MESSIER 101

*From a photograph taken at the Mt. Wilson Solar Observatory*

# A BEGINNER'S STAR-BOOK

An Easy Guide to the Stars and to the Astronomical Uses of the Opera-Glass, the Field-Glass and the Telescope

By

KELVIN McKREADY

With Charts of the Moon, Tables of the Planets, and Star Maps on a New Plan

*Including Seventy Illustrations*



G. P. PUTNAM'S SONS
NEW YORK AND LONDON
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1912

The Knickerbocker Press, New York

To

M. and D. and G.

who have watched with me at the threshold

No unregarded star
  Contracts its light
Into so small a character,
  Removed far from our humane sight,

But if we steadfast looke
  We shall discerne
In it, as in some holy booke
  How man may heavenly knowledge learne.

WILLIAM HABINGTON, 1634.

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"Some amateurs, I am told, believe that their efforts are rendered futile by the more powerful equipment and better atmospheric advantages of other investigators. If this feeling were well grounded, it might fairly be asked whether the great observatories are worth their cost. For the history of astronomy teaches that much of the pioneer work has been done by amateurs, usually with modest means and in unfavorable climatic conditions. We may therefore inquire whether useful work of such a nature as to contribute in important degree to the advancement of science can still be done with simple and inexpensive instruments. This question may at once be answered in the affirmative. Far from believing that recent developments have been detrimental to the amateur, I am strongly of the opinion that his opportunities for useful work have never been so numerous."—*A Study of Stellar Evolution*, by GEORGE ELLERY HALE, Director of the Mt. Wilson Observatory, pp. 243; 23; University of Chicago Press, 1908.

# Preface

THIS book has been made in the hope that it will prove of service. It is, in a sense, but one effort more to help those who are without technical equipment to claim through the unaided eyes, or through simple optical instruments, their heritage in the things of the sky. And yet the book would not have been undertaken but for the conviction that it represents certain new and useful departures in scope and method. For a fuller statement of these I must refer to the introductory pages.

While intended for the general reader I trust it may also prove of value in some of our educational institutions. Many a teacher of sound culture and adequate training who would like to observe and would like to help others to observe, has had no opportunity to know the use and possibilities of the small telescope. Most of the manuals of observation assume as already known many of the things that the beginner chiefly desires to know—both as to the stars and the instruments employed.

In dealing with the practical side of observation I have tried, therefore, to be explicit and to be definite. I have not avoided repetition but have tried to employ it in the interest of clearness and usefulness. I have attempted also to meet the small problems the very existence of which—when once overcome—the experienced observer has been altogether too likely to forget.

I have not given the volume the form or manner of the text-book; for, as already stated, it is especially intended for the general reader. And yet as a book for supplementary use, and as a simple observational manual, it may be employed concurrently with any of our modern volumes on astronomy. It is not unlikely that a little actual experience in observation will give broader value to the use of such texts both by the general reader and by the student, and may add an interest to the theory and mathematics of the science. Even where there is no formal course in "astronomy," the student will find a real gain to pleasure, to imagination, and to a larger conception of the universe in the mere experience of intelligent observation. It is worth while to know something of the things of the sky, not merely from a picture or a lantern slide, but with that sense of actuality which comes from seeing the things themselves.

The volume is also intended for those who wish to add to their knowledge of the skies without optical aid of any kind. Even to readers unable to use a telescope, the information as to the telescopic objects among the stars, in the moon, etc., is of interest and value. While, therefore, such information is kept distinct, it is presented in close connection with the more popular discussion of the moon, the planets, and the constellations. Tables are included indicating the positions of the planets in their course through the stars, month by month, till the year 1931.

The telescopic objects are grouped directly under the Key-Maps in three different classes,—(*a*) those for the opera-glass and field-glass; (*b*) those for telescopes of 2 inches, and (*c*) those for telescopes of 3 inches, in aperture. Though almost all the selected objects are, therefore, extremely easy, they nevertheless afford abundant opportunity for larger instruments. Indeed, I trust that advanced students will not find the general apparatus of the book, its diagrams, maps, etc., unsuited to their needs,—for great care

has been taken to preserve accuracy of statement, to avoid the making of a mere "wonder-book," and to keep the volume in touch with the better sources of information. Much of it is, necessarily, a recapitulation of elementary facts; it is frankly a book for "the beginner"; and yet I have worked in the conviction that the beginner is peculiarly entitled to soundness and sobriety of statement. The facts themselves are sufficiently interesting, without embellishment or exaggeration.

How much of success has been attained I cannot judge. The whole literature of the subject is so replete with detail that it is impossible wholly to eliminate the factor of error. Those who know the subject best will, therefore, be the most generous in judgment; for these will know, as none others can, what to the author must be the labor-cost of even so elementary an undertaking.

Many of my obligations are expressed in the brief bibliography at the close of the volume. The data as to star magnitudes are, for the most part, from the *Revised Harvard Photometry* (1908). For the measures of double stars, for the magnitudes of components not given in the *Harvard Photometry*, and for much other technical information I am indebted to the *Sternverzeichnis* of Ambronn (Göttingen, 1907). The results there given are, of course, largely compilations from Burnham and from other sources, but the volume is none the less admirable as a general summary of stellar information. For the data as to the distances of the stars I am indebted to the *List of Parallax Determinations* by Kapteyn and Weersma (Groningen, 1910). The plan for showing the stars in a dark sky, with key-maps to the same scale, was first suggested to me by Müller's *Atlas* to his *Kosmische Physik*. Supplementing this general method with certain features suggested in *The Midnight Sky* (by Dunkin of the Greenwich Observatory, 1872), and adding certain practical features gained in the personal experience of observation, I have tried to secure a composite result—a result based upon sound precedents and yet representing a real advance in the mapping of the skies for popular use. Of the specific plan and method of the maps I have written at length in the introductory pages.

In closing these brief acknowledgments I must record my thanks to the Yerkes Observatory, to the Mt. Wilson Observatory of the Carnegie Institution, to the Lick Observatory, and to Dr. Percival Lowell, Director of the Lowell Observatory, for the use of photographs. I wish also to thank my friend, Mr. Burtis B. McCarn of Chicago, for much admirable work in the drafting of the maps; and finally I would say that in the arrangement, plotting, and articulation of the maps and diagrams, and in the assembling of the technical data, I am indebted to the coöperation of a devoted hand to which I am not permitted to make public acknowledgment, but to the generosity of which I am something more than grateful.

K. McK.

New York City,
January, 1912 A.D.

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# A BEGINNER'S STAR-BOOK

## I. Introduction

### Our Heritage in the Stars

My first impulse was to name this book "The Stars—with Astronomy left out." I have not done so, and yet such a title would represent no serious misstatement of its purpose. It is a purpose sincerely consistent with the most grateful estimate of astronomy as a science. But just as there may be a pleasurable familiarity with the flowers, without any very great knowledge of botany, so there may be a pleasurable knowledge of the stars without any very large acquaintance with the technicalities of astronomy. Indeed the pleasure of the stars may be the pathway to their science, just as a homely, familiar knowledge of the flowers will often lead to an understanding of their botany.

Such a suggestion is in harmony with the better and happier educational methods of our time. We are learning to awaken and develop the natural enthusiasms which make the true geologist by taking our classes into the hills and the fields; we are teaching natural history by seeking to interest the beginner in the animal life about us. In almost every department of education we are now trying to go, first of all, to the objects themselves; and we are seeking to build up our knowledge less upon a basis of discipline and convention and more upon a basis of interest. And yet in astronomy we still find, altogether too often, that the pupils in our schools are compelled to busy themselves with the angles and circles of the celestial sphere, with the grim mystery of solstices and nodes, before they have been brought face to face with the friendly realities of the sky.

So is it, also, with the general reader of adult years—for whom this book is more especially intended. Even our more popular manuals of astronomy too frequently assume that the mathematics of the science are already known,—or, if not already known, must necessarily be learned. There are many pathways to the pleasure of the stars. To the minds of some the way of mathematics may be, instinctively and naturally, the best method of advance. Some of the greatest of astronomers—such as Newton himself—were primarily mathematicians and were never very great observers. But for most of mankind, *observation* in its most elementary sense—observation finding its primary impulse in the simple pleasure it awakens—must be the method of approach. The purpose of this book is, therefore, to take the reader directly into the presence of the stars, showing the beginner when to look and where to look, and what there is to see.

As knowledge is increased, the field of interest is enriched. While the volume is an attempt to begin with the beginner, it also attempts to go on with him. It seeks to provide, at least in some measure, for the larger interests that may be awakened. Without intruding into the field of theoretical astronomy, I have thought it well to add, in the chapter devoted to each subject, such general information as may help to quicken and

develop the broader knowledge of the observer. These facts are stated in untechnical language, and they are intended to be suggestive rather than complete. In the hope, moreover, that the reader may be moved to seek elsewhere for fuller materials, the names of a few useful books—some elementary and some that are more technical—are added at the close. But sufficient information and guidance are given in the present volume to advance the beginner at the very opening of his study to a use of the simpler optical instruments, and to direct him at once to the more interesting telescopic objects.

## The Unaided Eyes

Much can be done, and much known, without optical aid of any kind. The science was founded by men without telescopes. The Egyptians, Hebrews, and Arabs had none; Copernicus had none; Kepler, even, had none—or had none till after he had made all his larger contributions to astronomy. And yet an elementary knowledge of the familiar stars—knowledge easily within the grasp and interest of the average child of twelve—is wholly left out of the lives of multitudes of men and women largely because it is assumed that in order to know the stars they must have elaborate instruments. There are many who may well send up Carlyle's oft-quoted plaint: "Why did not somebody teach me the Constellations, and make me at home in the starry heavens which are always overhead and which I don't half-know to this day?" By reason of such ignorance the world is, I think, the poorer.

For, after all, astronomy is not the most important thing, by any means, that the stars have to teach us. To know them is to know a world that is intrinsically beautiful, a world full of the immense and the illimitable—and yet not vague, inchoate, confused, but coherent, and of exquisite precision in the definiteness and consistency of its order. Really to dwell in such a world and to dwell in it intelligently and responsively is to be more completely "at home" within the universe in which we live,—for Carlyle's phrase is just. And if there be "no time" in our hurried and busy generation for a sense of the mystery and order of the stars, is not this itself one of the reasons why we should *take* time for them, and for the healing power of those silences to which they league their unceasing invitations? Our life, just now, is not too rich in imagination, nor too deeply moved by the sense of reverence or the touch of wonder.

First of all, therefore, and as a basis for all that any optical instrument may contribute, I have attempted in this little book to bring the reader to such a knowledge of the stars as may be acquired by the employment of the unaided eyes and the average mind. But both—the eyes and the mind—must be *employed*. Not that the task is at all exacting. Indeed I am familiar with no other class of useful and interesting information so quickly or readily acquired by the beginner. I am speaking, of course, not of technical astronomy but of the stars themselves—their groupings, their movement, their seasons, their individual characteristics. But eye and mind must be employed—not disemployed, as is too often the habit of those who flit vaguely and absently from topic to topic among the various fads of the "nature-lovers' " cult,—really seeking anything but nature and loving nothing but the vague sense of being "broad." Yet fifteen minutes of real reading by day, and (even more important) fifteen minutes of attentive looking at the actual sky by night, will shortly put the real clues of the subject into the hands of any interested learner over the age of twelve. Young people who know their way about the skies as familiarly as they know their way to the post-office are not more remarkable mentally than those who do not; they are as real as the boy who can easily quote the batting averages of his favorites

in cricket or base-ball, or the woman who can quote the prices on the fur coats in the ten shops just visited, or the man who has no trouble remembering "quotations" on 'change. It is merely a question of being interested.

### Opera-Glass and Field-Glass

In learning to identify the star-groups, or constellations, an opera-glass is always useful. While not essential, such an instrument is of value partly because it adds greater brilliancy to some of the richer star fields, and partly because it will often aid the beginner in locating the fainter stars and in more readily tracing the outlines of the constellation figures. This is especially true on misty nights. On nights distinctly foggy, waiting is the better part of science. The stars will return again; and an optical instrument, from the least to the greatest, will not work many wonders in bad weather.

The advantages of the opera-glass are possessed in even larger degree by the modern "field-glass," or prism binocular. Many of these, unfortunately, are almost as expensive as a telescope, but while lower than a telescope in magnifying power they are extremely convenient in size and their uses are more varied. Those who already possess such a glass will gain great pleasure from its use at night, and those who do not own either an opera-glass or a binocular will find on p. 97 some further instructions as to the selection and cost of instruments.

We cannot say that their use, valuable as it is, is wholly necessary to a pleasurable knowledge of the stars. Still less can we say that the occasional use of optical help, however great, will ever serve as a substitute for the interested, intelligent use of the unaided eyes. Yet as we use our eyes, most of us wish to see better than we do; the use of an opera-glass soon makes us wish to use a field-glass or a "spy-glass"; and the use of these will soon suggest, at least in many cases, the larger possibilities of the telescope.

### The Small Telescope

The impression that the really fascinating interests of astronomy are solely within the scope of large and expensive instruments is quite unfounded. All the *characteristic* subjects of observation are within the scope of simple and inexpensive glasses. It is true that optical aid, of some kind, is desirable. The almost inconceivable distances of space can be partly traversed by our unaided vision, but it is absurd to claim that without optical assistance of any kind we can see just as well as though we had a telescope. The glass need not be large. It may magnify but fifteen times or twenty times or sixty. But in each case there is a gain. Indeed, with a glass magnifying only two times the object is brought twice as near. With a glass possessing a magnifying power of twenty or a hundred the object is brought nearer by twenty or a hundred times, and, if there be sufficient aperture, is made to appear proportionately brighter or clearer to the average eye.

So wide, however, are the reaches of the universe that even such changes do not always endow our objects of vision with impressive "size." The largest subjects take on dimensions that to the beginner seem of very meagre bulk. Yet the real telescope, however small, will show—as I have said—the characteristic objects of astronomic interest. It may not show all the star-clusters, but it will show enough to illustrate charmingly just what a star-cluster is. The small instrument will not show all the double stars or all the

conformations upon the surface of the moon; but to the real observer it will reveal stars of varying colors—double, triple, and quadruple; and it will make the face of our moon a spectacle of increasing fascination. Its larger mountains, "seas," and "craters," indeed more than two hundred features of its topography, stand out in clear relief. Objects such as these, together with the crescent phase of Venus and the four larger satellites of Jupiter are easily within the scope of a 2-inch* instrument; and a telescope of 2¼, 2½, or 3 inches will show these objects—and many others—under still better conditions of light and power. The photograph of the double cluster in Perseus shown on the opposite page was taken with a large instrument; but the existence of the cluster may be detected with an opera-glass, and much of its beauty and impressiveness may be caught with even the smallest of telescopes. At a cost of from $20 to $150, according to size, quality, and equipment, the average man or woman can command an instrument that will open a new world of abundant and varied interest.

## The Sky and its Maps

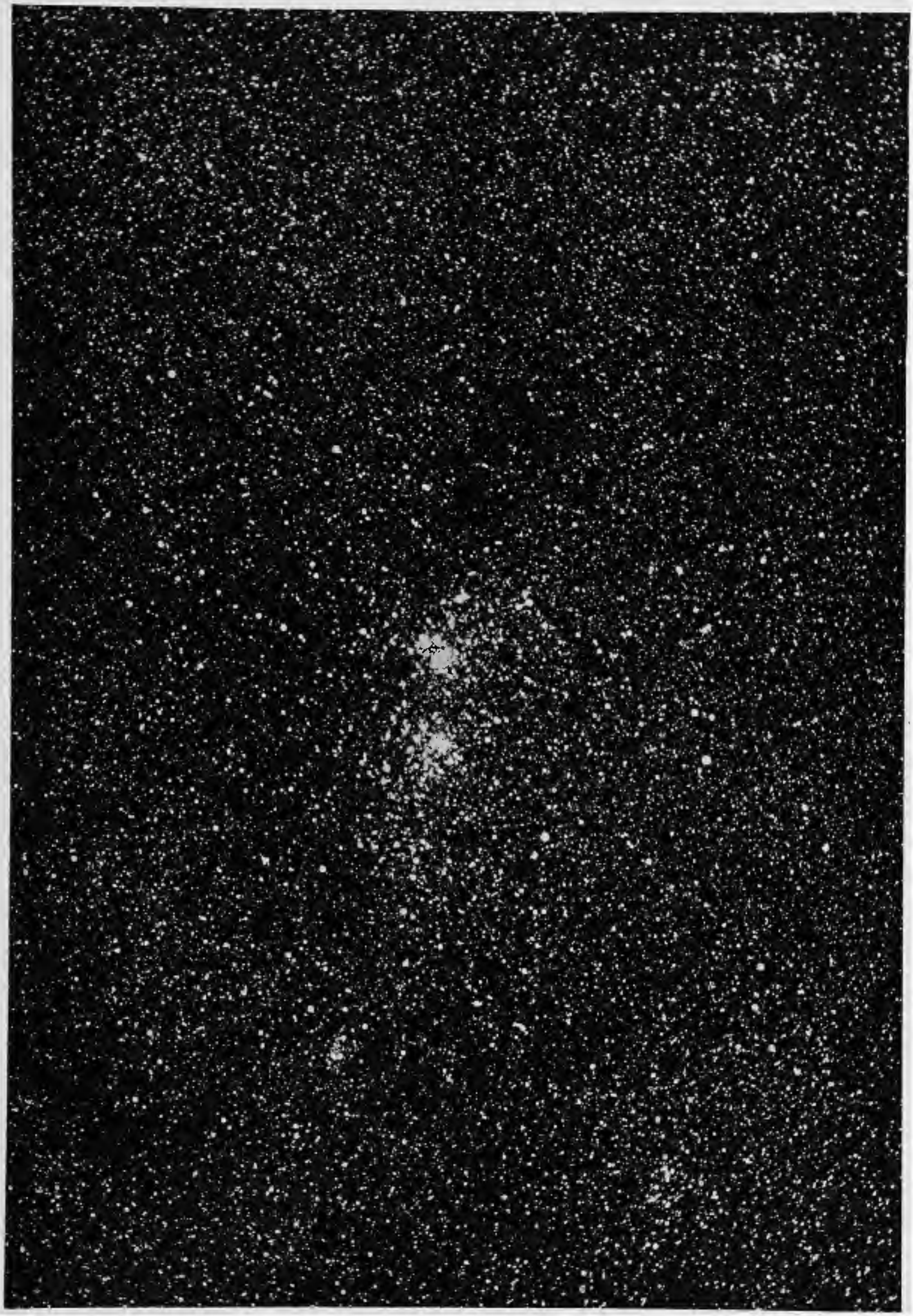
I once asked an accomplished watcher of the skies how he had managed to begin, and to begin successfully. His reply was—"I had a friend." There could have been no better answer.

There is, indeed, no better help toward learning to recognize the stars and the star-groups of the sky than the friend who knows and who is able and willing to teach. But such a friend is not always present; and it sometimes happens that such a friend, even when present, will crowd so much into his occasional opportunities for instruction that the resulting impression, to the beginner, is bewildering rather than informing.

In any case, and however deliberate the instruction, a chart or map is always helpful; and such an aid is especially important if no friend be right at hand. Here, however, we meet one of the real difficulties. The vault of the sky does not appear to us as a flat surface but as "an inverted bowl." Our earth seems to us to revolve on its axis at the centre of a hollow sphere, lighted from the sun by day and from the moon and the stars by night. As we look away to the horizon, whether toward the north or east or west or south, we seem to be gazing not at a flat wall but at concave impalpable surfaces which, bending inward, meet at the zenith overhead.

Now if these northern or western or eastern or southern skies *were* flat, it would be a simple matter to map them precisely as they are. But just because these surfaces are not flat but like parts of the inner surface of a hollow sphere, we cannot draw or print them on a flat surface without causing a certain amount of distortion in the picture. This distortion is not great at the centre of the map, but at the edges we must always remember to allow for it in comparing the map with the actual sky. In order to reduce this distortion as far as possible I have here abandoned the attempt to present the whole sky in a single map. Two maps are given for each "sky," one showing the stars as the observer faces directly north, one as the observer faces south. But where, at the edges of the maps, distortion does appear, it has seemed best to face it frankly;—not to ignore it or conceal it but to deal with it as inevitable, to point it out, and to show—so far as possible—how we may allow for it and correct it.

* Telescopes are usually classified, as to size, according to the surface diameter of the lens at the large end of the instrument. A 2-inch telescope, and a 3-inch, are telescopes in which these lenses are, respectively, 2 inches or 3 inches in diameter. A 2-inch will bear a magnifying power, for the average eye, of from 15 to 70 diameters; a 3-inch, from 25 to 110 diameters. These are low estimates. The trained eye can of course utilize far higher magnifications. See, for further practical suggestions, pp. 104, 110.



**REGION OF THE DOUBLE STAR CLUSTER ($h$, $\chi$) IN PERSEUS**

*From a photograph taken at the Yerkes Observatory*

In at least one other respect the system of mapping here adopted will be of special service. The reader is provided not only with a series of Key-Maps on the right-hand pages, but also with a series of Night-Charts, on the left hand, showing the actual sky, without lines or symbols. The observer is thus enabled while looking at the pages of his book, to enter more easily into the mental experience of relating the night sky to a printed map. This—even where there may be some distortion—is a more important privilege than the veteran star-gazer has always realized.

Usually, the beginner must look at a map in a book, a map somewhat crowded with lines and symbols, and then go look at the sky. The sky to which he turns has on it, however, no lines, no letters, no symbols. Just because the beginner *is* a beginner, the mental experience of relating lines, letters, and symbols to a real sky (and a dark sky at that) which has on it no such markings, is wholly new. The task is likely to seem even more difficult than it is; and it often proves discouraging. Through the use of the Night-Charts here provided, the beginner easily learns, from the Key-Map opposite, how to associate the lines and symbols with the uncharted sky. He can enter into this new mental experience by easy, deliberate stages and at his own convenience. Having first "done it in a book," it will be much easier to do it afterward in the open. And in using the book it will often prove interesting to cover the Key-Map with a card, and test, by first looking at the Night-Charts alone, just how much of one's star-lore has been remembered. The same general method has been followed with the moon. On the left-hand pages are photographic reproductions of the actual moon, on the right-hand pages—drawn to the same scale—are the numbered Key-Maps.

Because the stars repeat themselves, there will be much repetition in the text. Because intended primarily for the beginner, these repetitions must extend not only to the objects of observation but to methods. The repetition of elementary facts and suggestions may prove an irritation to the fastidious, but as the volume is intended for *use* rather than as a book merely to be read, there seems to be no alternative.

The beginner may at first think that the Night-Charts and their Key-Maps are rather full, presenting too many stars and too much detail. They are not fuller, however, than the sky. Some books upon the subject do present only one star-group at a time; and some—while presenting all the area of the sky—reduce the number of objects in the picture by omitting most of the smaller stars. But if we present the sky at all it is best, perhaps, to present it just as it is or as nearly so as we may. A few of the smaller stars have been omitted, but should we leave out all of the smaller stars we should often have to omit some of the most characteristic features of a group; and in presenting only one group at a time we should have to omit one of the most interesting phases of the subject—the relation of the groups to one another.

Two additional reasons have seemed to me important: I have wished to make the volume not only a good book with which to begin, but, as already suggested, I have tried to make it also a book with which to go on. Not that the advanced observer will care to stop short of manuals larger and more technical; their use will be both interesting and necessary. And yet the simpler book, if sound in method, should not be so simple as to be outgrown before the aid of more pretentious manuals can possibly be utilized. Secondly, the detail of the maps has seemed to me to be justified by the needs of the telescopist. It has always seemed to me absurd to declare that the intelligent beginner must postpone the pleasure of using a small instrument till he has mastered the constellations. The telescope would be used far more largely both in our schools and in private hands if the beginner could quickly learn where the objects of interest may be found, and how to point

the instrument under the guidance of clear maps directly related to the actual sky. Such needs, and others of like nature, the drawings of this little volume are intended to meet. By placing the general descriptions of the star-groups directly under the Night-Charts on the left, and the descriptions of telescopic objects directly under the Key-Maps on the right, we are able to introduce the amateur very early in his study both to a knowledge of the constellations and to the direct use of the telescope.

It is not unlikely, however, that the maps will seem, at the first, unduly crowded—in spite of what has just been said. The skies themselves are full of variety and detail; the subject—to the beginner—is new, its vocabulary unfamiliar, its symbols strange. What wonder, therefore, that he cannot "lazy himself into it" as he might lazy himself into a new game. But the subject is not difficult. Its possibilities are quickly available. Its rewards are not delayed. They come with the first steps, and with succeeding steps are richly multiplied. One suggestion, however, should be kept in mind: "Proceed slowly, at the first." Do not attempt too much at once. Get clear strong grasp on what you do learn. Take one thing at a time. In such case, each item of progress may be made a secure basis of association; group may be added to group, fact to fact, till suddenly —as one learner, in delighted amazement, expressed it—"the constellations will seem to walk down to you out of the sky."

Your landscape here upon our earth may change with each mile of your journeyings. Your skies, however, will remain. Whether in San Francisco or New York, whether in London or Florence, the same skies, approximately, will arch themselves over you, and spread above you "the loved familiar roof of home." They will unite you with past ages and older cultures, whether Biblical, Oriental, Greek, or Roman, just as they unite you to the lands of the present. And while they touch the larger emotions and open broader horizons to the mind, the imagination to which they speak is not that vague illusion of the inchoate which a superficial hour so often confuses with the splendor of the sublime, but the imagination which springs from the evidences of precision and exactitude, from the sense of method and the bracing consciousness of law. It is a wholesome world in which to think and dwell.

> "Plainness and clearness without shadow of stain!
> Clearness divine!
> Ye heavens, whose pure dark regions have no sign
> Of languor, though so calm, and, though so great,
> Are yet untroubled and unpassionate;
> Who, though so noble, share in the world's toil,
> And, though so task'd, keep free from dust and soil!
> I will not say that your mild deeps retain
> A tinge, it may be, of their silent pain
> Who have long'd deeply once, and long'd in vain—
> But I will rather say that you remain
> A world above man's head, to let him see
> How boundless might his soul's horizons be,
> How vast, yet of what clear transparency!
> How it were good to abide there, and breathe free;
> How fair a lot to fill
> Is left to each man still!"

Matthew Arnold: *A Summer Night.*

NEBULA IN CYGNUS, KNOWN AS N. G. C. 6992

*From a photograph taken at the Yerkes Observatory*

## III. Objects to be Seen: The Stellar World

### WHAT ARE THE STARS?

ONE will often note in some current "Almanac" the statement that Venus or Mars or Saturn or Jupiter is the evening or morning "star." The expression, however familiar, has led to much misunderstanding. In the strict sense, Venus, Mars, Jupiter, Saturn, Mercury, are not stars at all. They do not shine by their own light. They are *planets*, as is our Earth also, shining by the reflected light of the Sun. About the Sun, these, together with the other planets, Uranus and Neptune, revolve; and they are—with their attendant moons—the most important factors in what is called the Solar System, *i.e.*, the system of the Sun, or the system having the Sun as centre.

The stars, in the stricter sense, lie far outside this system. Let us note for a moment the comparative distance from our Earth of the very outermost of the known planets and the very nearest star. The planet at the greatest distance from the sun, and from the Earth also, is Neptune, *larger* than our globe, but so far away as to be invisible to the naked eye. Neptune is 2792 millions of miles away. That seems, indeed, a vast distance. Yet the very nearest of the stars proper is more than 8000 times as far, is distant—in fact—more than 25 millions of millions of miles.

If, therefore, some of the stars seem small to us as they "twinkle" in our night skies, it is only because they are so very far away. And if some of them seem large and bright, it is not necessarily because they are very near. It is because, although at vast distances from our earth and from our whole solar system, they are so immensely great in size. Most of the brilliant stars are actually nearer than the fainter, but Deneb,—one of the brighter stars in our sky—is also one of the more remote. Nor is Deneb unique. Most of the stars are indeed superbly large and brilliant—many of them being far larger and brighter than our sun. For our sun itself is a star (strictly, of course, our nearest star), and all the stars are suns—suns set so inconceivably far away in space that in many instances their radiance comes to us only as a trembling point of light. We have thus answered the question, What are the stars? We know them to be suns, suns shining by the intensity of their heat.

### STAR DISTANCES

So far away are the fixed stars that the mile as a unit of measurement becomes almost meaningless. Astronomers have therefore sought a longer "yard-stick" and have taken for this purpose the distance travelled by light—speeding at a velocity of 186,324 miles a second or over 11 million miles a minute—in a year of time. This unit of measure, or "yard-stick" of the universe, is called the light-year. The nearest of the fixed stars thus far measured is Alpha ($\alpha$) in Centaurus, not visible from our northern latitudes. This star is 4.3 light-years distant. The nearest of all the bright stars visible in Europe and North America is Sirius, 8.7 light-years distant. In other words, the light from Sirius which reaches our eyes to-night started on its way more than 8 years ago. Or, to state

the same fact somewhat differently, should Sirius be blotted out to-night, we should know nothing of it for more than 8 years. A table giving the latest measures for about 50 of the important stars will be found on p. 139.

## Star Magnitudes and Star Symbols

Because some, at least, of the fainter stars are nearer than some of the bright ones, and because some of the bright ones are farther from us than many of the faint ones, we do not attempt to classify the "magnitudes" of the stars according to their actual size. We base our classifications of magnitude not on the size or nearness of the star in itself, but on the relative *brightness* of the star as viewed from our earth. So careful and exact has been the work of astronomers, that every star that our eyes can see, without a telescope, is not only registered in well-known catalogues and star-maps, but each star has assigned to it a specific magnitude based on actual observations made with instruments of high precision.*

Of these, six different magnitudes, or degrees of brightness, are recognized. A sixth-magnitude star is barely visible with the unaided eye, even under good atmospheric conditions; a fifth-magnitude star is a little brighter, and so on till we reach the brightest—the stars of the first magnitude. A few of the stars, however, are so very much brighter than the *average* first-magnitude star that decimals of unity, figures lower than 1, have been called into use. The star Sirius, indeed, is classified as of magnitude −1.6, which means that it is over ten times as bright as a star of precisely the first magnitude; nevertheless Sirius is listed, in a general way, among the stars of the first magnitude. It is thus always important for the beginner to remember that the smaller the numeral of classification the brighter the star, and *vice versa*. Of first-magnitude stars there are twenty; a list of them will be found on p. 140.

The making of so brief a list as that on p. 140 will not seem to the beginner to present many difficulties, but that *all* of the stars of the six larger magnitudes should be accurately listed and classified will seem almost incredible. Their number, as we look upward on any clear and cloudless night, will at first seem fairly limitless. Yet, including all of the first six magnitudes, there are really only about 5000 such stars—stars visible to the unaided eye—in the total sphere of the heavens. As we see only half this number at once (for naturally we cannot survey the skies beneath our feet), the number visible at any one time must be reduced to about 2500. When we realize moreover—as has often been pointed out—that those near to the horizon are largely obscured to us by mists, trees, houses, etc., it is evident that the number actually before us at any given hour is even smaller. Newcomb puts the total at from 1500 to 2000. The use of a telescope will, of course, bring multitudes of others into view.

Even so small a number as 2000 will doubtless seem, at first, to be so bewildering as to make any definite knowledge of the sky altogether impossible save to an observer with special gifts of mind or training. But this is by no means the case. If the stars greatly changed their position from night to night, confusion would be inevitable. But, though making their apparent revolution once each 24 hours, their places *in relation to each other* have been practically unaltered for unmeasured centuries. As we watch them, we quickly learn mentally to group the fainter ones about the brighter, according to outlines or figures

* The two most important catalogues of the stars by magnitudes are that made by the Royal Observatory at Potsdam, Germany, and that made by the Observatory of Harvard University, U. S. A. A list of the 70 brightest stars is printed on p. 140, showing their relative magnitudes.

that have descended to us from the past. Some of these traditional groupings seem to us illogical, but inasmuch as an attempt to change them (and to secure agreement as to the change) would only increase confusion, they have been retained.

SPIRAL NEBULA, KNOWN AS MESSIER 51

*From a photograph taken at the Yerkes Observatory*

In one respect, however, a change has already come. The ancient world saw in these groups of stars the figures of birds or animals or mythological heroes. These fancies served, for many centuries, a useful purpose. It was possible to designate the location of a star, for example, by reference to it as the brightest star in the head of the Dragon, or in the left foot of Andromeda, or in the head of Taurus, the Bull. But this method

was necessarily crude, and never very accurate. In the seventeenth century (1603), a German astronomer named Bayer published a series of star-maps in which most of the brighter stars in each group were designated by letters of the Greek alphabet.* Roman letters came also to be employed, as well as our ordinary Arabic figures, 1, 2, 3, etc., so that these shorter and easier symbols have gradually passed into universal usage. For readers of this book who may be unfamiliar with the Greek characters I have ventured to simplify in two ways the using of these symbols. First the whole Greek alphabet, with the names of the letters, is printed on p. 33. As many, however, will not wish to trouble themselves to memorize the alphabet as a whole, I have also given in the text itself the English names of the Greek letters wherever used—for example, the Beta ($\beta$) of Perseus; the Gamma ($\gamma$) of Andromeda, etc.† Thus, the beginner who has no knowledge of Greek will not only be able to follow the notes below the maps in their references to the stars, but will soon gain—almost without knowing it—a working knowledge of the Greek symbols.

The old mythological *names* for the star-groups or constellations are still retained. So also we still keep the ancient names for many of the individual stars. But the figures and shapes of heroes, etc., are usually so difficult to discern, so many are now quite uncertain in outline and without real helpfulness to the beginner, that they are falling more and more into disuse. In this book, while some of the more obvious are pointed out in the notes, I have frankly omitted them from the maps. Experience has convinced me that they are not of serious value in the learning of the constellations and that the effort to trace them sometimes withdraws attention from the interest of the stars themselves. For the stars themselves, in the light of our modern knowledge, possess an ever deeper intrinsic interest.

## The Double Stars

With our earliest use of the telescope, however small, we shall find that we must add to the list of the 1500 or 2000 stars visible in our sky. Not only shall we see many stars not seen before, but stars noted quite clearly with the unaided eye will now be seen to be *two* instead of one. Castor, for example, one of the brightest stars in the constellation Gemini, is thus found to be a "double." Each of the components, if these could be set farther apart in the sky, would prove bright enough to be clearly seen without opera-glass or telescope. They are really so near together, that the two stupendous suns look to the unaided eye like one star. A magnifying power of 70 will show their separation. The companion orbs are in revolution about a common centre of gravity; and Castor is therefore called a *binary*. We shall come upon other binaries as we take up the study of our maps.

We shall find also that not only are some of the stars binary in character but that there are cases in which the components are so close together that no telescope will ever be able to divide them. The division has been detected by the spectroscope; and these

* The suggestion had first been made by the Italian, Alexander Piccolomini, in 1559. For all technical purposes astronomers now designate the positions of stars by right ascension and declination, the celestial equivalents of longitude and latitude, see note 14, p. 32.

† In many text-books, and in the technical literature of astronomy, the references to individual stars are made merely by the use of the Greek letter in connection with the Latin genitive of the constellation name. For example, the star Alpha ($\alpha$) in Lyra, is thus written $\alpha$ *Lyrae;* Delta ($\delta$) in Orion, is written $\delta$ *Orionis*, etc. Knowing that there are many interested students of the stars to whom Latin and Greek forms are confusing, I have not only included the English names of the Greek letters, but have used English prepositions for Latin genitives. We may thus simplify the course of the beginner without sacrifice of accuracy. See also p. 141.

stars are therefore called spectroscopic binaries; see p. 143. Castor—to which we have just referred—is really a quadruple object; for each of the components visible in a small telescope is itself a spectroscopic binary.

There are also triple stars, and quadruples, etc., as well as doubles. Some of these are apparently bound together in interdependent systems like the binaries, revolving about a common centre; some, upon the other hand, are merely "optical" doubles or "optical" triples,—stars not truly bound together, but placed in the same line of sight when viewed from our position on the earth. Their apparent nearness to one another is wholly deceptive. In other cases, however, the relative nearness of the components to each other is so evident, and their revolution about a common centre of gravity is so fully proven, that the observation of double stars is one of the most delightful interests of the possessor of a small telescope.* Some of these true doubles, as we shall see, are sufficiently "wide" to be divided by a field-glass.

They become all the more interesting when we note that the separate components of the double or triple stars are, in many cases, of different colors. In the star marked Gamma ($\gamma$) in Andromeda, for example, the larger component is a golden yellow, the smaller a delicate emerald. In that marked Alpha ($\alpha$) in Hercules, the larger star is a light yellow, the smaller component a dark blue; and in other cases, also, the two components are of contrasted tints, yellow and white, yellow and green, orange and purple, white and gray, yellow and red. In some of the more striking cases the impressions of color are illusory, but there are also many cases of true color-distinction. Observers are often disagreed as to their impressions—as is often the case in our impressions of color in other objects—and there are instances in which the stars seem to have *changed* their colors, somewhat, since the earliest period of observation. The subject is accordingly full of interest and charm. In the calm, unhurried watching of a double star through a good instrument on a clear moonless night, one has the same exquisite pleasure as that awakened by the flash of two contrasted jewels, each enhancing the subtle thrill and radiance of the other. The smaller component, as it clings close within the light of the larger, will often look like a tiny dewdrop trembling within the splendor of some golden globe. The observer knows that he is really gazing upon two mighty suns at so great a distance from us that the imagination is utterly inadequate even to its elementary appreciation and that these close-bound stars revolve about their common centre probably divided by many hundreds of millions of our earthly miles. Yet a night which lies thus about us wearing suns for jewels never loses its appeal even for the hardened astronomer. The expressions of enthusiasm for the wonder of the stars, of delight in their mystery and charm, have chiefly come in every age not from the "mere amateur"—as the cynic might suggest—but from Kant or Laplace, from Kepler, the Cassinis and the Herschels.

### The Variables

In the Autumn of each year, through the hours of the early evening we shall find at the northeast (or in Spring at the northwest) the star known to the Arabs as "Algol." In maps of the stars it is usually marked as Beta ($\beta$) in the constellation Perseus. (See Key-Maps on pp. 47 and 59). Algol shines usually as a star of the second magni-

* Speaking of Tennyson's remarkable knowledge of the stars and of the accuracy of his poetic references to scientific matters, Sir Norman Lockyer says: "I visited Tennyson at Aldworth [his home] in 1890 when in his 82d year. One of the nights during my stay was very fine, and he said to me, 'Now, Lockyer, let us look at the double stars again,' and we did. There was a two-inch telescope at Aldworth. His interest in astronomy was persistent until his death."—*Tennyson as Student and Poet of Nature*, by Sir Norman Lockyer and Winifred L. Lockyer, London, 1910.

tude. At regular intervals, however,—and these intervals are so regular that they may be predicted to the fraction of a minute,—its light begins to fail. Within 4½ hours it loses more than half its brilliance. It stays at "minimum," its point of faintest brilliancy, for 20 minutes; and then, in approximately 3½ hours its light again increases until it once more reaches the brightness of a second-magnitude star. After remaining at its greatest brilliancy for 2½ days, its decline begins anew. There are known at present more than 1000* variable stars, although the stars of the Algol type are only about 80 in number. Most of the variables are too small, however, to be seen with the unassisted eye; but some of the brighter of these stars are easily observed without optical aid of any kind.

The true explanation of the variations in Algol was suggested as early as the 18th century, but no final proof of its validity was afforded till the more recent researches of Vogel, Pickering, and Chandler. The chief point of interest to the beginner is that Algol is attended by a dark companion, the two bodies being in revolution about a common centre of gravity or about another body invisible with our instruments. As Algol passes behind its dark companion, the dark companion is interposed between Algol and our earth. Thus the brighter star is eclipsed by the dark one, and this eclipse corresponds to Algol's period of lowest brilliancy. As the revolution proceeds, the brighter star passes from the shadow of eclipse, and its normal brilliancy returns.

The star known as Mira—marked Omicron (o)—in the constellation Cetus (Key-Maps pp. 61, 41) is quite different in type. Its period of change is much longer—sometimes 10 months, sometimes 11. It is usually invisible to the naked eye, but at intervals of a little less than a year it becomes sufficiently bright to be recognized, gradually increasing in brilliancy till it reaches its maximum, and then, within less than 3 months, sinking again so low as to be wholly invisible except in a telescope. Its precise degrees of brilliance, both at its faintest and at its brightest, are as irregular as its periods. At its maximum it shines sometimes as a star of almost the first magnitude, but more frequently as of the second or third. At its minimum it falls to magnitude eighth or ninth or tenth. Unlike the case of Algol, no adequate explanation of the variations of Mira has as yet been found. There are several other types of interesting variables each having many representatives, but for these I must refer the reader to the more general text-books on astronomy, noted on p. 144. Mira reaches its greatest brilliancy at intervals of 10 or 11 months,—for 1911 in July; for 1912 in June; for 1913 in May, etc.

## Star Colors and Star Character

We have already found, in connection with the double and multiple stars of the sky, that the components of such bodies are often different not only in size but in color. A little careful attention, however, will show us that *color* is a characteristic of all the stars, whether double or single. At a first view on a clear, moonless night, all may seem alike; but closer observation will show that while some are white, some also are yellow, others are a deep orange, others red. Says Sir Norman Lockyer: "The stars shine out with variously colored lights. Thus we have scarlet stars, red stars, blue and green stars, and indeed stars so diversified in hue that observers attempt in vain to define them, so completely do they shade into one another. Among large stars, Aldebaran, Antares, and Betelgeuze are unmistakably tinged with red; Sirius, Vega, and Spica are of a bluish white; Arcturus and Capella show a yellow hue like that of our sun.

* If we include those comprised within star clusters, and not classified individually, the total would be nearer 4000. Additional variables are discovered each year.

SPIRAL NEBULA IN COMA BERENICES, KNOWN AS H. V. 24

*From a photograph taken at the Mt. Wilson Solar Observatory*

"In double and multiple stars, however, we meet with the most striking colors and contrasts; Iota ($\iota$) in Cancer, and Gamma ($\gamma$) in Andromeda, may be instanced. In Eta ($\eta$) of Cassiopeia we find a large white star with a rich ruddy purple companion. Some stars occur of a red color, almost as deep as that of blood. What wondrous coloring must be met with in the planets lit up by these glorious suns, especially in those belonging to the compound systems, one sun setting, say, in clearest green, another rising in purple or yellow or crimson; at times two suns at once mingling their variously colored beams! A remarkable group in the Southern Cross produced on Sir John Herschel 'the effect of a superb piece of fancy jewelry.' It is composed of over 100 stars, seven of which only exceed the tenth magnitude; among these, two are red, two green, three pale green, and one greenish blue."

Impressions quite so striking are not within the range of the unaided eye, nor even within range of the instruments available to the average amateur, but the varied beauty of the familiar star colors as seen in ordinary telescopes will find increasing appreciation as knowledge grows and as mind and eye become more practised in the art of accurate discrimination. As we have already seen, there is much authority for the contention that colors other than the various degrees of white, yellow, and red are due to optical illusion; but, where—as here—these "illusions" are permanent factors in our scene, even as viewed by the best eyes and the best instruments, they remain for the practical observer as legitimate impressions. The questions as to how these illusions arise, and as to how they may be said to differ from the admitted hues of white, yellow, and red, only add to the interest of the subject.

A star, moreover, is not a timid flame lighted in a chimney corner. We have seen that among all the stars visible to the unaided eye from the latitudes of Europe or North America, Sirius is the nearest. And of all the fixed stars of the sky it is the brightest. Yet as its very light, at a velocity of over 186,000 miles a second, takes more than 8½ years in which to reach us, we are not surprised to learn that it is more than 20 times as luminous as the sun. The star Rigel, shining at the lower right-hand corner of Orion, see pp. 41, 45, seems not quite so bright. Is it therefore a smaller sun? On the contrary, its real luminosity exceeds that of the sun by 8000 times. Why then should Sirius seem the brighter? Chiefly because Rigel's distance from us is so vast that the light from it which meets the eye to-night started on its long journey more than 450 years ago, or before the birth of Shakespeare.* Betelgeuze, the other first-magnitude star in Orion, is not so bright nor so far away—being at a light distance of about 100 years—but, upon the other hand, its mass has been conservatively estimated† at more than 22,000 times the mass of the sun. Bodies so huge in their proportions and so splendid in the energy of their effulgence are not easily to be described, either as to their constitution or their color, by a simple label. As to each star, the prevailing color may be red like Betelgeuze or yellow like our sun, but as we watch it closely we are likely to see the torrential flash and interplay of more varied hues. Such is especially the case with Sirius; so is it also with Rigel and Vega and Capella. Indeed, as to the factor of color, we may well say that each star is of many stars compounded. And yet each has its own general hue, for each is itself and not another.

Each one of these far off suns, as we come to know it, and to consider not its color alone but the factors of magnitude, of motion, of distance,—its place in the sky, its relation to

* Kapteyn accepts the almost insensible parallax of Gill and Finlay (0.″007), undoubtedly the most accurate thus far obtained. See the table of parallaxes and star-distances, p. 139.

† *Problems in Astrophysics*, by A. M. Clerke. A. & C. Black, London, 1903.

other stars, the seasons of its rising and setting,—will be found to possess an individuality of its own. We soon come to know it and to count upon its friendly shining. Even though we may not always be familiar with the varied facts or discoveries concerning it, its identity will become, in instinctive ways, familiar. It is said that an old tailor when testifying in court was once questioned as to certain stitches in a coat. "They are my stitches," said the tailor. "How," asked the judge, "do you know they are your stitches? Are they longer than the stitches of others?"—"No, your honor."—"Are they shorter?"—"No, sir." "Then how," exclaimed the judge, "can you claim that they are yours?" "Do you think, your honor," replied the tailor, "that I do not know *my* stitches?" And the testimony stood.

How seldom, indeed, can we give particulars as to friends that we have known. Was the hair dark or blond? Were the eyes blue or gray or brown? Was the mouth small or large? We cannot always say. But when we see the face, its identity is clear; we know it. How often, watching at dusk when the fainter stars are hid, and looking out to the horizon, we see a flash of slender light just at the brow of some far off hill or down an opening lane through a neighboring wood,—a star returning at twilight, after a long absence. At the moment we may not know it, but at a second look the mind leaps in recognition—it is Regulus, or Capella, or Vega, or Antares; old associations throng within us; memories of other recognitions, of congenial spirits who with us once watched its rising; of changes that have come; of changes that have not come, but that still wait the will and the labors of men. Thus is it that the return of the stars may be as the greeting of old friends.

## Star Clusters and Nebulæ

While the stars, therefore, possess an individual identity, there are instances in which we can know them only in masses or clusters. Just as men and women, however distinct they may be in their own personalities, will often seem from the standpoint of a spectator to "lose themselves in a crowd," so is it with the stars. At certain points in the sky we find them gathered so close together that it becomes impracticable to try to distinguish them from one another. These dense masses of stars are called "clusters." Some of these are visible only in a telescope, though the telescope need not, in all cases, be a very large one. Two of the most beautiful, however, are visible to the unaided eye; and here, at least, not all the larger stars are lost in the mass;—some of them shine out with marked individuality. One of these clusters is called the Pleiades and one the Hyades; both are in the constellation Taurus, the Bull. In our notes upon the maps (see pp. 40, 46, 58) we will indicate their position more precisely.

The Pleiades* begin to appear at the northeast in our evening skies (8 P. M.) about October 1st; and as the stars rise each evening about 4 minutes earlier than on the evening before, we shall see them each night at 8 P. M. a little farther advanced upon their way. In January, at the same hour, we shall find them, accordingly, too high overhead for convenient observation; but by April 1st, we shall again find them conveniently placed for observation at the northwest. As the stars make the complete circle of their apparent revolution once in every twenty-four hours, we can anticipate this yearly march through the months—if we desire—by "watching out the night." The sun's shining will of course make them invisible by day, but we may be quite sure that the Pleiades are actually in

* "Many a night from yonder ivied casement, ere I went to rest,
Did I look on great Orion, sloping slowly to the west.
Many a night I saw the Pleiads, rising thro' the mellow shade,
Glitter like a swarm of fireflies tangled in a silver braid."

Tennyson: *Locksley Hall.*

our sky—at all seasons of the year—about 16 hours out of every 24. The watching of such a group for a few nights, not out of a window but under the actual sky, will, in itself,

**LARGER STARS IN CLUSTER OF THE PLEIADES**

(*For view at culmination, the side to reader's right should be held downward*)

*From a photograph taken at the Yerkes Observatory*

prove a good beginning in astronomy and will do more to make clear the apparent motion of the stars than any amount of theoretic description. (See also pp. 22 and 24.) I say

"apparent" motion, because of course the movement of the stars, in the sense in which I have here employed the word, is not *real*. It is our earth that really moves.

Let us assume that about October 1st we are looking at the northeast (nearer east than north), and that at 8 P. M. we discern the five or six brighter stars of the Pleiades just rising above the horizon; at 9 P. M. they will be higher still. Indeed, if the horizon is shut off by high woods or tall buildings, or by clouds or fog, we may have to wait till 10 P. M. before we can get a good look at them. At corresponding hours on November 1st or December 1st they are, of course, higher up. See also, p. 134.

To the average eye, under fair conditions, five or six stars in the Pleiades can be seen: under especially good conditions, seven. An abnormally good eye can see from eight to ten. With the use of an opera-glass—the average opera-glass magnifies about 3 diameters —as many as twenty can usually be counted. The use of a modern prism binocular, magnifying from 7 to 10 diameters, will reveal more than fifty; a small telescope will add many more; a large telescope will add almost a thousand; and, finally, the camera will bring the total to nearly 2500—for, inasmuch as the photographic plate is more sensitive than any eye, the camera when adjusted to the telescope will reveal many stars that are beyond the reach of any instrument employed without photographic aid. No instrument gives a more beautiful representation of such a cluster than the small telescope with a low-power eye-piece.

The use of low magnifying powers in the observation of clusters and nebulæ is essential, as will be more fully set forth hereafter. Other clusters will be indicated in direct connection with the maps. The location of the double cluster in Perseus, of the "Bee-hive" in Cancer, and of several others—if the night be moonless and very clear—can be made without optical help, but there can be little appreciation of their real beauty without the aid of a field-glass, or a small telescope; though even an opera-glass—especially when brought to bear on some of the coarser groups—is no mean assistance. We may say, indeed, that the whole Galaxy or "Milky Way" is in one sense a cluster. Spanning the sky "as a beautiful belt of pale light" it makes—when the moon is not shining—one of the most marvellous fascinations of a summer evening. Turning an opera-glass or field-glass upon it, we discover that it is not a mere waste of glowing cloud but that it is composed of thousands upon thousands of stars—stars that seem small because of their great distance from us, but which are, in many cases, far larger than our sun. The telescope, as we shall see in our study of our Key-Maps, will show that certain sections of it are peculiarly beautiful and impressive.

The nebula is sometimes found in connection with the star cluster, as in the Pleiades themselves, but it is often found apart, and it is not strictly star-like in composition. Even when associated with such a cluster as the Pleiades the nebulous matter may be very faint—beyond the reach of average telescopes—and yet the stars which it enfolds may be large and bright. To use an imperfect illustration afforded by other conditions, we may say that a nebula looks as though it might be a tiny isolated patch of the Milky Way, but in its structure and composition it is gaseous. Sometimes this filmy mass is oval, sometimes quite irregular, in form; sometimes it will seem to throw out wisps and streamers of effulgence, or, again, as shown in the illustration on p. 8, it will seem to us like the long and shelving undulations of a thin cataract of light, as it slips from star to star in its shining fall through space.

Some of the most remarkable nebulæ are spiral in form, and their luminous gases seem charged with star-like condensations, though no telescope—however great—has ever resolved these points of condensation into true stars. Some astronomers regard the

nebulæ as stars in process of formation, others regard them as stars in process of disintegration. In certain cases the nebulæ seem to be involved in a vast whirlpool

THE GREAT NEBULA IN ANDROMEDA, MESSIER 31

*From a photograph taken at the Yerkes Observatory*

motion, throwing off their streams of light and matter as a whirlpool in a flood seems to throw off its frothing waters from its centre. But so great is their distance from

us or so inconceivable their magnitude that we have caught as yet no visual evidence of change.

The nebulæ, however, are not brilliant objects in small instruments. They are disappointing except to those fortunate enough to command facilities far beyond the range of the average purse. And yet it is of interest to get such glimpses of them as we may, even if we may not be able to command an impressive view of them. For even the highest optical aid can do little more than afford a suggestion of the facts. The longer diameter of the great nebula of Andromeda is more than 500,000 times the distance which divides our Sun from the Earth; p. 118; and light, speeding from end to end of this mass

THE GREAT NEBULA IN ORION

*From a photograph taken at the Yerkes Observatory*

at more than 186,000 miles a second, must take eight years in which to complete the journey. The mere observation of such an object is worth while, however inadequate our view of it; and something of the beauty of at least one of these mysteries of the sky—the great nebula of Orion—is, as we shall see, within the range of our smaller instruments:

> "a single misty star,
> Which is the second in a line of stars
> That seem a sword beneath a belt of three.
> I never gazed upon it but I dreamt
> Of some vast charm concluded in that star
> To make fame nothing."

TENNYSON: *Merlin and Vivien.*

## III. Learning to Observe: Four Key-Groups

BEFORE taking up the larger maps the beginner will find it helpful to study the simple outlines of two or three of the smaller groups. The stars that I have chosen are not in all cases complete constellations but conspicuous groups that are easily and quickly identified. By first learning to distinguish these, the task of learning to identify other groups is made easier and simpler. These key-groups become "guide-posts."

They also serve another and more important purpose. Drawing them—as we shall try to do—in closer relation to our actual horizon than is possible with the larger maps, we can perhaps see more clearly just how these star-groups look, not only at their highest apparent altitude, but when they are rising and setting. With the star-groups toward the north, in the neighborhood of the pole, the problem of life-like drawing is quite simple. First of all, therefore, let us take the familiar "Dipper,"—sometimes, in England and Canada, called the "Plough."

### LOOKING NORTH—ALL SEASONS

The seven stars which form the "Great Dipper" are always in our northern sky. That we do not see them by day is wholly due to the fact that the daylight hides them.*

The Sun is so much brighter than any of the stars that, whenever its light is in our sky, the stars are blotted out. But toward the day's close—if the air is clear—we can begin to see the brighter stars, and as the night comes on we find that the stars have been above us and about us all the while. As we watch them we soon see that they, like the Sun, seem to move from east to west; taking about 24 hours to complete their round. This—as in the case of the Sun—is, however, only an *apparent* motion. And there is another apparent motion of the stars,—that which brings us the star-changes of the seasons. In each case, that which really moves is, of course, the earth. One of these movements is that of the earth through its orbit round the sun; the other movement—on which we here dwell—is the earth's rotation on its axis.

We know that as we sit in our car in a railway station it will sometimes seem to move when that which moves is not our train at all, but the train just outside. So as our earth turns on its axis once in each twenty-four hours the stars themselves do not revolve, but they do *seem* to revolve within this period of time. The axis on which they seem to turn will thus coincide, of course, with the axis of the earth—except that this axis will be longer, and its ends will seem to extend outward through the stars to north and south.

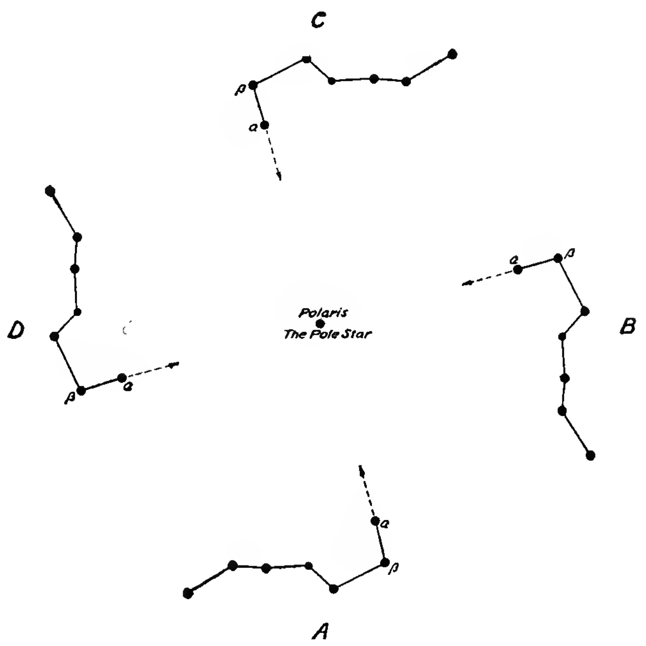
Just as the north pole of the earth, for example, is the "top point" of the earth's axis (a point, like the centre of a wheel's hub, which seems not to revolve, but round which the earth turns) so is it with the apparent wheel of the stars. Its central

* "Earth's dark forehead flings athwart the heavens
Her shadow crown'd with stars—and yonder—out
To northward—some that never set, but pass
From sight and night to lose themselves in day."

TENNYSON: *The Ancient Sage.*

hub is thus at a point in the sky corresponding to the pole of the earth. If we can find this hub we may be sure that at this point there will be no motion of the starry sphere; that round it the other stars will seem to turn; that as we come nearer to it their circles of revolution will grow smaller (just as the circles of revolution in a wheel grow smaller as we look closer to the hub) until, at the pole itself, there will seem to be no motion at all. This will all be clear to us as we watch the movement of the Great Dipper.

Let us assume, for example, that on November 20th (a few days earlier or later will make little difference) at about 8 P. M. we are looking at the northern sky. At 8 P. M. on that date the Great Dipper will be found due north in the position marked A. You will see that it is low down, near the horizon, and that the stars marked Beta ($\beta$) and Alpha ($\alpha$)




FOUR POSITIONS OF THE DIPPER

are pointing upward toward a bright star located about midway between the horizon and the zenith (the zenith is the point directly overhead). This star is called "Polaris" or the Pole Star.

If you will look northward again in a couple of hours you will see that the Dipper has moved. You will find it passing on its way from position A to position B. You will note, however, that no matter what its position, the stars $\alpha$ and $\beta$ are still pointing toward the Pole Star. You can see the Dipper advance from position A to position B in about 6 hours, if you care to maintain your watch so long. In six hours more you will find it very high up, at position C. It will then pass to position D, and thence to position A again.

And you can see it pass through all these positions without sitting up any later, if you should prefer to look at it—through the course of the year—for a few minutes at about 8 o'clock each night. For on each night the stars complete their round just about four minutes earlier. They are, so to speak, always "four minutes fast." Each night at 8, therefore, after November 20th, the Dipper will be a little farther along than position A, so that at our chosen hour by February 20th the Dipper will be found not at position A but

at position B. By May 20th, at about the same hour, we shall find it high overhead at position C. At the same hour, on August 20th, we shall find it at position D; and at about 8 P. M. on November 20th, we shall find that it has completed its circle and is once more at position A. All this will be made much clearer than it can ever be stated in a book if the beginner will take this simple diagram in his hands, turn to the north, and put real eyes on the real stars for one or two consecutive evenings.

But, whether we really observe a little or read a little or do a little of both, there are four facts that will soon be quite clear. We shall note, first, that the stars are in apparent revolution about a central pole; secondly, that the stars in the Dipper marked Beta ($\beta$) and Alpha ($\alpha$)—called the "Pointers"—are always pointing in the general direction of this pole; thirdly, that the star Polaris—alone among the stars—seems not to move; and fourthly, that the polar-point around which the stars revolve must therefore be at, or very near, this star.

The fact is, of course, that the pole is not exactly at the star Polaris. Polaris, however, is so near to it that it may fairly be called the Pole Star and, if we could place ourselves precisely at our north pole, Polaris would seem to stand almost directly overhead, like a tiny celestial capstone to the projected axis of our earth.

While, therefore, this star also revolves about the pole—the exact pole of the heavens being of course only an imaginary point—yet, because Polaris is so very near the pole, the circle which it makes, as it revolves, is quite small—so small that, for all ordinary purposes, the star seems to stand still. A star placed, however, a little farther from the polar-hub will, as the great wheel revolves, make a larger circle; and the farther from the pole we look—among our northward stars—the larger will be the circles of revolution. Of the two Pointers, Beta ($\beta$), of course, will mark a greater circle as it revolves than the star Alpha ($\alpha$). And yet all the stars of our sky that are no farther from the polar-hub than the outermost star of the Dipper, can describe their circles of revolution without being carried below our horizon. They are always, therefore, in our northern skies.

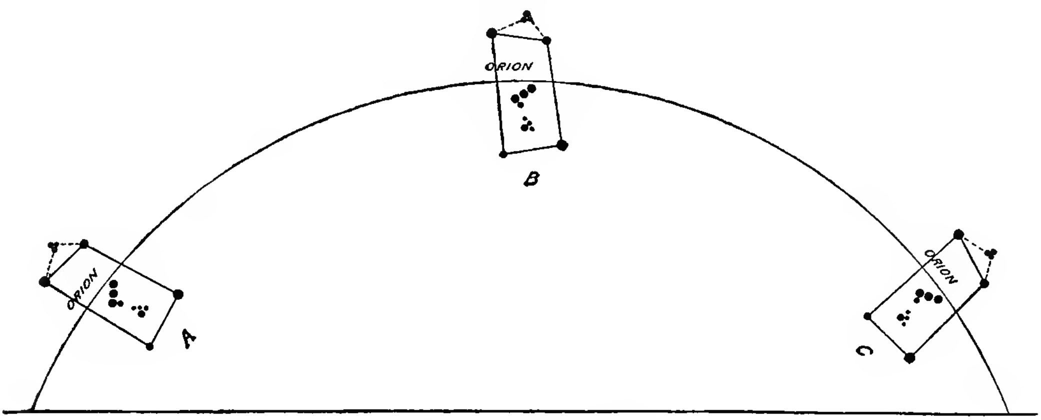
The stars, however, that are placed somewhat farther from the polar-hub will necessarily, as the wheel turns, dip below the horizon for a longer or shorter period; and the farther they are from the pole the longer must they be below our horizon and absent from our skies. These stars, as our earth turns on its axis, will seem therefore to rise and set. Moreover, as we come to study them we shall see that our figure of speech must be changed. For as we face the north and look at Polaris we are gazing not strictly at the hub of a flat wheel, but—as we have said—toward the pole of a hollow sphere, its apparent axis the projection of the earth's axis, and its equator the projection of our own equator. We may therefore imagine the spokes of the revolving wheel—as they extend—gradually bending inward toward us, and forming the ribs of a vast including globe. We stand—inclosed as it were—at the sphere's centre.

The circumpolar stars turn with the sphere itself, but as they lie so near the pole, the circle of their revolution never carries them out of sight. Sometimes, as we face the north, we find the Dipper above the Pole Star, sometimes below it; sometimes it is a little to our right, slowly climbing upward as in position B. Sometimes it is a little to our left, with the bowl turned downward as in position D, but it is always before us in our northern sky. Yet with the sphere's turning, the stars *farther* from the pole, like bright points fixed on the inner surface of its concave sides—as these arch themselves above and below the horizon—appear and disappear according to their hours and their seasons. Let us make this still clearer by turning to another of our key-groups.

## Looking South—November to April

We are now to look at a star-group quite far from the pole. So wide is the circle which it makes in its daily revolution that its stars not only dip below the horizon, but are really above it for only about 10 hours in the 24. As it is so far from the pole we will face now towards the south. On the same evening, November 20th, let us first realize as we face southward that we have put the pole at our backs. The east, therefore, will be now at our left; the west will be at our right. At 8 P. M. on November 20th, the stars of Orion, perhaps the most beautiful of the constellations, begin to appear low down in the eastern sky.

By 9 o'clock these stars will probably be clear of the mists that in Autumn so often lie at "the edge of the world"; and by 9:30 or 10 they will be well placed for observation. This group is now, let us assume, at position A, with the three bright stars that pass diagonally through the great square, pointing upward;* by 1:30 A. M. it will reach position B; by 5 A. M. it will reach position C; by 8 A. M. it will have set.




THREE POSITIONS OF ORION

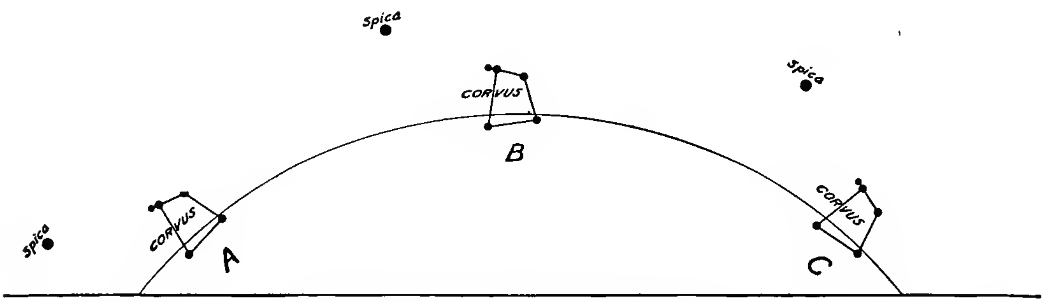
Most of us, however, do not care to watch through a whole night, even to follow the march of such a constellation as Orion. We will prefer to follow the other method. Remembering that the stars rise each evening four minutes earlier than on the evening before, we can just as well follow Orion through his march across the sky by looking for him through the hours of the early evening at successive dates. We shall need more time than one night or one week or one month. As Orion comes to position A four minutes earlier each night, so it will be four minutes earlier when he reaches position B; and by 8 P. M. in January we shall find these stars nearer to B than to A. At 8 in February they will be quite at B, and by 8 P. M. in April they will be at C. We shall thus have almost six months in which we shall find Orion conveniently placed for observation among the stars of the early evening.

This little diagram is placed at this point, however, not only in order that we may follow the course of one star-group, but in order that we may also get some idea as to how Orion looks as he rises and sets. The impression given in the diagram is not perfect. I have already explained that—inasmuch as the stars are not arranged on four straight

*"Those three stars of the airy Giant's zone
That glitter burnished by the frosty dark."
Tennyson: *The Princess.*

walls but seem to dot the inner surface of a hollow sphere—it is impossible to map them perfectly on a flat surface like the page of a book. But through such a diagram as we have just made, we can help to bring to ourselves a clearer picture of some of the positions of the star-groups that make the circles of their revolution far out from the pole. We can see how they slant, or tip, as they rise and set.

If we attempted in our larger maps to show this slant or tip for every group we should have to make a globe. We could not do it well on paper without involving ourselves in more technical and practical difficulties than the beginner would care to try to understand. This slant or tip of some of the constellations is, on the other hand, very quickly understood in the light of a little actual observation. Moreover, many of the star-groups show little if any distortion in the maps; and as we look farther from the equator and nearer to the poles north or south we find it less conspicuous. Let us take, therefore, another group. It is Corvus, the Crow (or the Raven); and near it we will place the bright star Spica (pronounced Spī′-ka).




THREE POSITIONS OF CORVUS WITH SPICA

Looking South—April to August

Those who have seen the figures of beasts and birds in the star-groups of the sky have here found the Raven's eye and beak in the stars at the upper left-hand corner, the feet at the corner just below, the tail at the corner diagonally across from the beak, and a half-opened wing at the upper corner to the right. Others have drawn or imagined the Raven quite otherwise;—for example, with the beak low down at the right as though picking up a grain of corn. All such "pictures" are interesting or uninteresting—according to our moods. . Let us find our chief interest, however, in the stars themselves.

The stars of this little group are not especially bright, but the outline which they present is clear and simple. It will give us additional light on the lessons already suggested, and we may gain from it at least two other helpful points.

Corvus rises at the southeast, shortly before the time when we find Orion setting at the west. On April 1st at 8 P. M. we shall find it a little above the horizon at the position marked A. If we follow it through its whole course in a single night, we shall find that by 11:15 P. M., Corvus has advanced to position B and by 3 A. M. to position C,—setting about 4 A. M. Or, as we have already explained in relation to Orion, we can follow its march across the sky by keeping an occasional look-out for it, from week to week, in the skies of the early evening. While at 8 P. M. on April 1st it will be found near position A, it may be observed—at the same hour—at position B on May 20th, and at position C by the 20th of July, unless the long daylight of July should then prevent our seeing it.

You will note, however, how constantly the bright star Spica follows it—how closely, in fact, Spica is associated with it in all the positions through which it moves. You will

see, therefore, not only how Corvus helps us to find and identify Spica, but how Spica—one of the brightest stars of the sky—will always help us to find Corvus under all sorts of difficult conditions of light and air. Spica does not belong to Corvus; it belongs to another constellation; yet just as one neighbor's house may help us to find another, so—in finding our way about the sky—there is much good use for neighbor-stars.

The association of Corvus and Spica in our little diagram will serve, therefore, as an illustration of a method, the method of learning the stars and of finding our way about the sky by the reference of stars and groups to one another. As the "fixed" stars are not conspicuously moving about in our heavens but have retained for ages their relative positions in the sky, the practice of connecting them mentally with simple lines of direction becomes full of interest and value. When, for example, your attention is once called to the fact that a short line from the two upper stars in Corvus will always go straight through Spica, the association thus suggested is not likely to be forgotten. In the same way, we have connected the Pointers in the Dipper with the Pole Star and we shall also see when we come to study Orion more closely that the row of three bright stars running diagonally through the centre will always point in one direction towards the superb white star Sirius and in the other direction toward the reddish star Aldebaran.

It is also useful, at times, to have a "yard-stick" in the sky, for we may be told that a certain star is this or that number of degrees distant from another star, or that a comet on a particular night will be found 20 or 30 degrees distant from the position of the Moon. Now 15 degrees is a fairly good yard-stick; and if we can remember that the distance from Spica to the near corner of Corvus is just about 15 degrees, that the distance from end to end on the shorter side of the great quadrilateral in Orion is also about 15 degrees, and that the distance across the top of the Dipper's bowl is just 10 degrees, we shall soon be able to get a very fair idea as to proportionate distances in the sky. While in this book I shall make few references to distance in degrees, yet there are times when a general idea as to what is meant by such references is of service to us all. I will therefore refer again to this subject in now turning to the last of our key-groups.

## Looking South—June to November

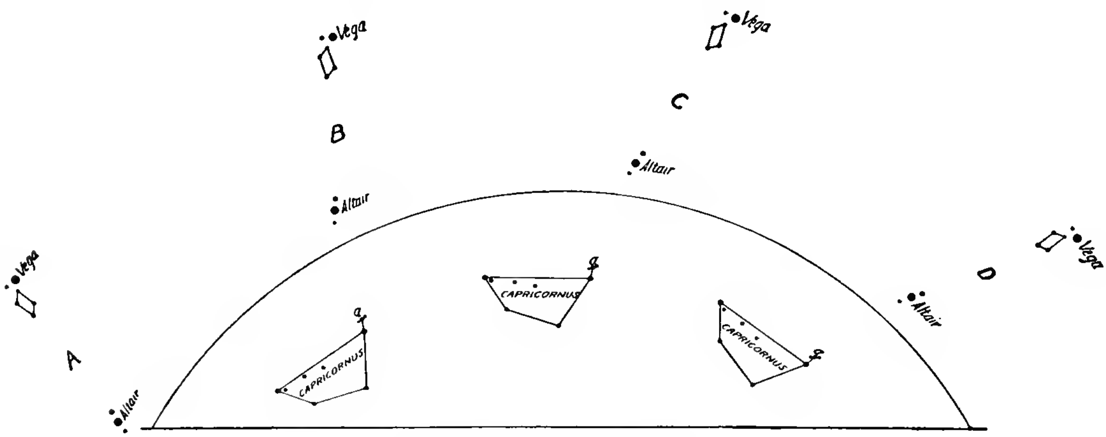
The star-groups at which we have been looking have been so plain in outline, and the relations they suggest have been so evident that I now prefer, in closing the series, to take something a little more difficult. I would say, however, as to the whole of this section on the key-groups, that if the beginner is not able to "make it out" at the first or second or third attempt, there need be no feeling of discouragement. The stars will be found at the times and places given them in the series of Night-Charts and Key-Maps; their direct observation is not dependent on an understanding of the "why and how" of their movements. The more we can understand, the greater our pleasure is likely to be; but it is also true that the more we watch and actually observe, whether with the telescope or the unaided eyes, the more certainly shall we understand. To assume, however,—as is so often done—that we cannot find pleasure and interest in the stars till we can clearly appreciate the theory of their motion is as absurd as to claim that we cannot enjoy a landscape or a sunset till we can explain the how and why.

As the month of June begins we shall find at 9 P. M. as we face southward that the bright star Altair and its two companions are rising on the left. As the stars rise higher and as the mists along the eastern horizon are left behind, they form a small but striking group.

The lowest star is not so bright as either of its companions, and yet—if the night be clear—these three almost equidistant points of light form one of the finest landmarks of the Summer sky.

By 9 P.M. on June 1st we shall find Altair at position A; at position B by 12:30 A.M.; at C by 4 A.M.; at D by 7 A.M., though lost in daylight. Or, preferring to watch it marching through the months rather than through all hours of a single night, we may observe it during the early evenings of June at position A, during the early evenings of July and August as it advances from A to B; and during the early evenings of September, October, and November from B to C and from C to D.

But there are two other groups in the sky, through practically the same hours, to which I would now call your attention. Altair and its two companions point—like a straight sign-post—in two directions. As they point upward we shall find them guiding us in the general direction of Vega, the white splendid star of the constellation Lyra. It is



FOUR POSITIONS OF ALTAIR

distant from Altair about twice as far as the distance between Corvus and Spica (now southwest as Altair rises) or thirty degrees. As Altair moves toward position B, Vega also will be found so much higher in the sky that, as we continue to face south, we shall have to undergo some discomfort in looking up at it. But toward this brighter star, Altair still makes, with its two companions, the same shining pointer from every position and at every hour.

And this pointer directs us downward as well as upward. By the time Altair reaches position B, we shall see—by looking closely—that there is below it at a distance of a little over 20 degrees a dim group of rather small stars,—the constellation Capricornus. It is called the Sea-goat, but it looks as little like a goat as Corvus looks like a Raven. Just because its stars are not bright and its outline faint, we shall find the direction given us by Altair and its companions all the more helpful. Indeed, it is always well, whenever possible, to make the brighter groups of stars serve as guides to groups that are more obscure. For the obscure groups often possess interesting features even to the beginner. Capricornus, for example, is one of the constellations through which the planets take their way in their march across the sky (see p. 80). It is also interesting to note that the star marked Alpha ($\alpha$) may at first seem to the observer to be single; but even an opera-glass will show that it is double, and that still another star is not far distant.

Here, however,—as with the other key-groups—I have called attention to the group,

not for the purpose of setting forth this or that detail, but in order to illustrate the different aspects assumed by certain of the star-groups as they rise and culminate and set. A star or a group is said to culminate when it reaches its highest point in its apparent march across the sky.

We have also learned how we may use our knowledge of one group to help us find another group; and I have dwelt on all these points here at the opening of this book for the reason that each of these suggestions can be taken up and utilized as a *method*, the beginner going much farther than I have here gone—seeing other lines of connection and association, and thus building up, through personal interest and initiative, a star-knowledge of his own.

The associations of such a knowledge will be enriched not only from our study of the skies but from the frequent references and allusions of conversation, of science, of letters. Words and phrases that were enigmas begin to have a meaning. Similes and metaphors that were quite barren become suggestive and fruitful. Much of the scientific news of the day and many of the noblest passages in the world's literature we no longer read with a sense of vague helplessness, but with at least some measure of comprehension. We know what month the American poet suggests as he refers to the hour "When Leo sleeps and Capricornus wakes"; and we can tell to what particular season Tennyson had reference when he wrote of the evening skies:

> "It fell at a time of year,
> When the face of night is fair on the dewy downs,
> And the shining daffodil dies, and the Charioteer
> And starry Gemini hang like glorious crowns
> Over Orion's grave low down in the west,
> That like a silent lightning under the stars
> She seem'd to divide in a dream from a band of the blest."
>
> TENNYSON: *Maud.*

GIACOBINI'S COMET, DECEMBER 1905.

*See Page 94.*

## IV. Star-Maps for any Year

THE USING OF NIGHT-CHARTS AND KEY-MAPS. SOME PRACTICAL SUGGESTIONS

1. The time-table of the maps is exactly indicated under the maps themselves. In the fuller schedule shown on p. 35 the black-letter figures indicate the hours directly covered by the map; the other figures represent the hours for which the map thus indicated is the best approximate help. For intervening dates the map nearest in point of time will prove quite adequate.

2. The notes under the Night-Charts on the left-hand pages will be chiefly used by those who wish to employ no optical instrument. The notes under the Key-Maps on the right-hand pages will be chiefly used by possessors of opera-glass, field-glass, or telescope.

3. As the planets are constantly changing their positions they are not given on permanent Star-Maps. On p. 82, fol., the places of the greater planets are indicated month by month for each month till the year 1931. Jupiter, Venus, Saturn, and Mars are usually such conspicuous objects when above the horizon that the beginner may find their march through the constellations a little confusing, for they frequently obscure the outlines of the star-groups as found in the maps. Directions for their easier identification will be found, therefore, in the special section, p. 80, on the Planets.

4. The Night-Charts and Key-Maps are thus strictly confined to the stars proper. Here are shown their relations to each other and their approximate positions in the evening sky throughout the year. The lower border of each map is intended to correspond with the horizon of the observer in the latitude of New York or Chicago. Observers as far north as London will see at the *horizon* a little less of the southern sky; those as far south as Richmond or Gibraltar will see at the *horizon* less of the sky to northward, but these differences need cause no serious confusion.

5. The upper border of each map corresponds, at the centre, with the sky overhead. The stars here are too high for convenient observation. And the stars at rising and setting are also inconveniently placed for observation, for the mists which so often obscure the horizon make difficult work both for the eyes and for the telescope. The notes placed below the Night-Charts and Key-Maps are chiefly concerned, therefore, with the star-groups that are well placed for immediate study. As all the groups repeatedly recur in the maps, the method thus indicated involves no neglect of any part of the sky. As you face due north or south begin with the sky directly before you.

6. In each case, however, the map represents somewhat more than the sky straight ahead. For each sky the map comes round a little to the right and left. In this way, the maps for north and south at any given hour cover much of the east and west also, practically presenting together the whole sky. But, as already explained (p. 4), the sky is a hollow sphere rather than a straight wall, and so there is necessarily some distortion in every map which attempts to put its figures on a flat surface. The beginner will quickly learn to adjust himself to this difficulty if he will begin the study of each map—in its relation to the sky—not at the top or at the sides but at the centre. Look straight away to the north or south, and work from the centre outward.

7. The presence of the Great Dipper, always in the sky, makes the northern groups easier to study than the southern. Moreover the southern groups, as explained on p. 25, are absent from the sky for extended periods of time. The direction of their apparent movement, from east to west, is shown by the arrows in the upper corners of the maps. In the maps of the sky southward these arrows may be taken to suggest not only the general direction in which the constellations move but the slant or inclination of the constellation-lines, as the star-groups rise and set. This apparent slant or inclination of these figures is more clearly and fully set forth on pp. 25, 26, and 28. We see that Orion and Corvus, for example, do not march straight across the sky as though the sky were a blackboard or a picture gallery but that they follow great curves or circles through the sky's vault. This is true also of Leo: the stars of the "sickle" rise first and are also the first to set. And what is true of these groups is true of all.

8. Some of the maps will seem to the beginner to be rather full of detail; but as soon as the chief groups are learned this impression will pass away. Not that all of the fainter stars can be seen when the sky is overcast with smoke or mist. Indeed it is only on the clearest nights, when the moon is not shining, that we can get much impression of the fainter stars even to the 5th magnitude. This is especially the case in large cities where the stars are dimmed or obscured by the diffused glare of many lights. But under good conditions the smaller stars do shine forth as "the host of heaven"; and so many of them are involved in the outlines of the constellation figures and so many are of telescopic interest that their omission would be impracticable.

9. In the study of the constellations the habit of frequently copying or drawing the outlines of the important groups will be found of great value. No matter how crude the results, and even if the observer can do no better than make a hurried sketch on the back of an envelope, the effort to record what is seen and remembered will prove a help to memory and will contribute to accuracy in observation. Naturally enough, the more carefully one draws, the greater the gain.

10. It should be said that in some of the maps a little more of the sky is included in the lower corners than can be seen at precisely the time indicated. For example, on p. 40 the constellation Canis Major, at the lower corner on the left, is not wholly risen at exactly 8 P.M. But as Sirius, its leading star, is then up, and as the whole group follows within half an hour, it seemed needless to omit the lower stars and thus sacrifice the usefulness of the map to the literal demands of a time-table. Here, and at other points as well, I have ventured to depend upon the common sense of the student.

11. In using this book out of doors at night it is well to be provided with one of the pocket electric flash-lights that are now available almost everywhere at very low cost. An ordinary bull's-eye lantern will do as a substitute. Better, however, than using the book out of doors at night—for any book is likely to suffer physical damage from such exposure—is the method now suggested: By using the Key-Maps in relation to the accompanying Night-Charts, familiarize yourself not only with a few clear groups but with the mental experience of relating the lines and symbols to the uncharted sky. Select your first groups not at the edges of the diagrams but as near directly north and south as practicable. Do not attempt too much at first. Then make your own drawing, on as large a scale as you like, of what you may expect to see. Take your lantern with you for the reading of your sketch, add to your sketch under the actual sky with your lantern's help, and—returning—compare the result with the maps in the book. The drawing is not essential; the method may be easily followed mentally without the drawing or the lantern; but care and precision are always worth while, especially at the first.

12. Telescopes are classified as to size according to the surface diameter of the lens at the large end of the instrument. A 2-inch telescope and a "3-inch" are telescopes in which these lenses are, respectively, 2 inches and 3 inches in diameter. Further explanations of telescopic terms, and directions as to the selection and use of opera-glasses, field-glasses, and telescopes will be found on p. 97. I have usually thought it well to underestimate rather than overestimate what may be accomplished with this or that particular glass; the average eye is at first incapable of utilizing the fullest power of an instrument. There must be a little experience. The beginner with a 2-inch telescope should therefore first find and observe the easier objects suggested for the field-glass; the beginner with a 3-inch telescope should first find and observe the objects suggested for a 2-inch; always beginning with the low-power eye-pieces. The easier objects are often the most beautiful, and it is a good principle to advance from simple tasks to greater rather than to rush to the greater, and to advance—only to disappointment

13. The numbers placed in brackets [ ] throughout the notes to the Night-Charts and Key-Maps are important. They refer to the items or paragraphs with corresponding numbers in the brief Observer's Catalogue, p. 116. There the reader will also find the pronunciation of star-names and fuller descriptions of the constellations, in alphabetical order. Fuller accounts of the nebulæ and of other objects are included. Observers possessing instruments with "hour-circles" will also find there the positions of the stars by right ascension and declination—the stellar equivalents for longitude and latitude. Information is there given as to the position angles of double and multiple stars as well as the data concerning the distances and colors of their components. Facts of this kind become of increasing interest to the amateur. They are placed in the Observer's Catalogue, however, partly to save space and partly because so much detail is likely, just at the first, to prove confusing to the beginner. The beginner is thus able to use the reference-numbers placed in brackets beneath the maps as much or as little as his interest and needs demand.

14. At the close of this book will be found maps of the two hemispheres of the sky, northern and southern. Here the constellations are all shown in their relations to each other, and the boundaries of the constellations are clearly indicated. The northern hemisphere includes a generous "overlap" of the southern sky in order that the beginner may find on a single chart most of the stars visible in Europe and the United States. The lines of right ascension and declination are here indicated: R. A. (or right ascension) representing the astronomical equivalent for longitude; S. D. (or south declination, sometimes called declination minus) representing degrees south of the celestial equator, and N. D. (or north declination) representing degrees north of it. The beginner need not go into the subject further in order to use the chart for his practical purposes in observation. If he reads in his morning newspaper, for example, that a new comet has been seen at a point in the sky described as R. A. XIX hours, forty minutes; and north declination (or declination plus) 10 degrees, he has but to turn to his map of the northern hemisphere, and note: that as the declination is given as N. (or plus) 10 degrees the object is not far from the equator, and slightly northward from it. As the equator is clearly shown (see the circle running through Orion, Serpens, Aquila, etc.) there only remains to be found the comet's position in right ascension. The R. A. of the stars is indicated by the lines running like the spokes of a wheel from the centre to the circumference of the map. These are marked at the border of the map for each "hour" in Roman numerals, from I to XXIV. As the right ascension in this case is given as XIX h., 40 m., the comet is evidently in the constellation Aquila, in the general

neighborhood of the star Gamma,—that star being not far from the point where a line marking R. A. XIX h., 40m., would cross a line marking N. D. 10°. Should the reader now desire to study this region of sky in one of the earlier maps he has only to turn to "Aquila" in the Observer's Catalogue where he will find the Night-Charts and Key-Maps in which this general region is mapped for evening observation. If Aquila be not then in the evening sky and if the part of the sky in which the comet is to be seen is above the horizon only at such an hour as 2 or 3 or 4 in the morning, the observer can easily find the equivalent Key-Map by remembering that the Key-Maps with their accompanying Night-Charts are just four hours apart. This search among the maps for the approximate place of a comet may sound a little difficult in the reading, but the process is really very simple "in the doing," and a little practice will make plain the way.

15. The English names of the Greek letters are always given in direct connection with the letters, wherever the Greek letters are used. Beginners who know no Greek—and their number, I regret to say, is growing—will soon learn these letters as they go along, without the necessity for learning the Greek alphabet all at once. For those, however, who may desire to memorize these characters quickly and as a whole, the Greek alphabet is here given in full. The vowel ē, where so marked, is pronounced as ā in bay; ō as o in slow; ŏ as o in won; u as ū in flute.

α Alpha; β Bēta; γ Gamma; δ Delta; ε Epsilŏn; ζ Zēta; η Ēta; θ Thēta; ι I-óta; κ Kappa; λ Lambda; μ Mū; ν Nū; ξ Xi; ο Ŏmicrŏn; π Pi; ρ Rho; σ or ς Sigma; τ Tau; υ Ūpsilon; φ Phi; χ Chi; ψ Psi; ω Ōmega. The pronunciation of the names of the constellations, etc., is fully indicated in the Observer's Catalogue. But, as to all technical pronunciations, whether of names or letters, it should be clearly understood that these are not fundamental to one's astronomical interest. If any word be used, no matter what the language, it is well for us to use it correctly, if we may. But of more importance are the stars themselves, and no one should allow ignorance or awkwardness in using mere terms, however ancient, to destroy one's pleasure in the stars. For their clumsy nomenclature the stars are not responsible; nor are the Greeks. Not till the 16th century of our era did the stars receive their Greek-letter designations. But an attempt at general changes would now bring confusion into the whole literature of astronomy.

16. Good photographs of star-clusters, nebulæ, etc., will often prove more impressive than views of the same objects through the telescope. The beginner need not be surprised, therefore, if his instrument fails to bring to the eye such pictures as this book contains. The camera has two advantages over any telescope, however large. First, the photographic plate is more sensitive than the eye, and will always reveal more—with any particular instrument—than any eye can see. Secondly, the camera, adjusted to the telescope, may be made by a clockwork mechanism steadily to follow an object in the sky for many hours—thus permitting a very long exposure of the plate. The sensitive plate thus receives and retains, not the impression of a moment (as the eye might) but the *cumulative* impression of hundreds of moments. This is of incalculable advantage in recording the fainter objects of the sky. The beginner will find, however, that his own direct views, through even a small telescope, will possess, in their actuality, a charm which no photograph can ever give. The author is under many obligations for photographs to the Lick Observatory, the Mt. Wilson Solar Observatory, the Lowell Observatory, Flagstaff, Arizona, and particularly to the Yerkes Observatory, Williams Bay, Wis. Most of these are acknowledged under the engravings. Where these acknowledgments are not explicit, credit should be given to the Yerkes Observatory,—especially for those of the moon.

## A Time Schedule of the Night-Charts and Key-Maps

See the Page Opposite

In the table here given the maps which are specially drawn for the dates and hours specified are indicated by the black-letter numerals. The schedule also affords, in each case, the best approximate map for the other hours of the same evening between 6 P.M. and 12 midnight. For example, on the evening of Jan. 1st, there are two sets of maps available, those for 8 P.M. on pp. 39 and 41; and those for 12 midnight, on pp. 43 and 45. But the latter will also do fairly well on that evening for 10 or 11 o'clock; and the former will serve fairly well for 7 or for 9. In the mid-summer months when the long-continued daylight obscures the stars till a late hour, the special map for the early evening (for 6 P.M. on Aug. 1st, for example) will be of little practical value in our latitudes; but the special map on that evening for 10 P.M. (for example) will meet every need. While this time schedule has particular reference only to the evening hours—showing the scope and use of the maps from, approximately, 6 P.M. to midnight—yet an observer who wishes to find the proper map for other hours may easily do so by remembering that the interval between the maps is just four hours. From one northward map to the next northward map is four hours. From one southward map to the next map looking southward is, similarly, four hours. The special maps for May 1st, at midnight, by the time schedule, are to be found on pages 51 and 53. The best maps for 4 A.M. on May 2d (four hours later) would therefore be the maps that follow next in the book,—those on pp. 55 and 57. The page references throughout the time schedule are always to the Key-Maps, the Night-Chart in each case being upon the left-hand page directly opposite. These references are indicated in the time schedule for the 1st and the 15th of each month; see next page. For all intervening dates the nearest map in point of time will be found adequate. The maps in which the various constellations are represented in the evening sky may be found by reference to the Observer's Catalogue. In a few instances, in which a large constellation is divided between north and south, reference to two successive northern or southern maps may prove desirable.

## TIME SCHEDULE OF NIGHT-CHARTS AND KEY-MAPS

The black figures show hours directly covered by maps; the other figures in same division show the hours for which the maps thus indicated are the be t approximate help. The maps for the sky as the observer faces north are in columns marked N; those for the sky as observer faces south are in the columns marked S. For further explanations, see opposite page.

| Date | Hour, p.m. | See Pages | Date | Hour, p.m. | See Pages |
|---|---|---|---|---|---|
| | | N S | | | N S |
| Jan. 1 | 6, 7, **8**, 9 | 39, 41 | Jan. 1 | 10, 11, **12** | 43, 45 |
| Jan. 15 | **7**, 8, 9 | 39, 41 | Jan. 15 | 10, **11**, 12 | 43, 45 |
| Feb. 1 | **6**, 7, 8 | 39, 41 | Feb. 1 | 9, **10**, 11 | 43, 45 |
| Feb. 15 | 7, 8, **9**, 10 | 43, 45 | Feb. 15 | 11, 12, **1** | 47, 49 |
| March 1 | 7, **8**, 9, 10 | 43, 45 | March 1 | 10, 11, **12** | 47, 49 |
| March 15 | **7**, 8, 9 | 43, 45 | March 15 | 10, **11**, 12 | 47, 49 |
| April 1 | **6**, 7, 8 | 43, 45 | April 1 | 9, **10**, 11, 12 | 47, 49 |
| April 15 | 7, 8, **9**, 10 | 47, 49 | April 15 | 11, 12, **1** | 51, 53 |
| May 1 | 7, **8**, 9, 10 | 47, 49 | May 1 | 10, 11, **12** | 51, 53 |
| May 15 | **7**, 8, 9 | 47, 49 | May 15 | 10, **11**, 12 | 51, 53 |
| June 1 | **6**, 7, 8 | 47, 49 | June 1 | 9, **10**, 11, 12 | 51, 53 |
| June 15 | 8, **9**, 10, 11 | 51, 53 | June 15 | 11, 12, **1** | 55, 57 |
| July 1 | 7, **8**, 9, 10 | 51, 53 | July 1 | 10, 11, **12** | 55, 57 |
| July 15 | **7**, 8, 9 | 51, 53 | July 15 | 10, **11**, 12 | 55, 57 |
| Aug. 1 | **6**, 7, 8 | 51, 53 | Aug. 1 | 9, **10**, 11, 12 | 55, 57 |
| Aug. 15 | 8, **9**, 10, 11 | 55, 57 | Aug. 15 | 11, 12, **1** | 59, 61 |
| Sept. 1 | 7, **8**, 9, 10 | 55, 57 | Sept. 1 | 10, 11, **12** | 59, 61 |
| Sept. 15 | **7**, 8, 9 | 55, 57 | Sept. 15 | 10, **11**, 12 | 59, 61 |
| Oct. 1 | **6**, 7, 8 | 55, 57 | Oct. 1 | 9, **10**, 11, 12 | 59, 61 |
| Oct. 15 | 7, 8, **9**, 10 | 59, 61 | Oct. 15 | 11, 12, **1** | 39, 41 |
| Nov. 1 | 7, **8**, 9, 10 | 59, 61 | Nov. 1 | 10, 11, **12** | 39, 41 |
| Nov. 15 | **7**, 8, 9 | 59, 61 | Nov. 15 | 10, **11**, 12 | 39, 41 |
| Dec. 1 | **6**, 7, 8 | 59, 61 | Dec. 1 | 9, **10**, 11, 12 | 39, 41 |
| Dec. 15 | 7, 8, **9**, 10 | 39, 41 | Dec. 15 | 11, 12, **1** | 43, 45 |
| Dec. 25 | 6:30, **8:30**, 9:30 | 39, 41 | Dec. 25 | 10:30, **12:30** | 43, 45 |

SPIRAL NEBULA IN TRIANGULUM, KNOWN AS MESSIER 33

*From a photograph taken at the Yerkes Observatory*

# The Night-Charts and Key-Maps For Any Year

NIGHT-CHART TO THE SKY AS THE OBSERVER FACES NORTH.
JAN. 1, 8 P.M., DEC. 15, 9 P.M., DEC. 1, 10 P.M., NOV. 15, 11 P.M., NOV. 1, 12 P.M.
FOR KEY-MAP TO THIS CHART SEE OPPOSITE PAGE.
FOR THE SKY AS THE OBSERVER FACES SOUTH, SEE PP. 40, 41.
For the sky at other Dates and Hours see Time Schedule, p. 35.

**The Constellations. For the Telescopic Objects See the Page Opposite.**

Numbers in brackets [ ] refer to corresponding numbered notes in Observer's Catalogue, p. 116.

As we face the north we now find the Great Dipper low down in the sky, wheeling slightly upward toward the right. Its apparent motion round the pole is described on p. 23.

Having found the Pole-star, let us note the group called "the Little Dipper," for the Pole-star is at the tip of its handle. Some of its stars are quite faint, and except with an opera-glass are not easy to see, save on very clear nights. The Little Dipper forms part of the constellation called URSA MINOR [405] or the LITTLE BEAR, just as the Great Dipper forms part of a larger constellation called URSA MAJOR [400] or the GREAT BEAR.

In each case the stars convey no clear impression of a bear, and such outlines of mythological or animal figures are so unimportant that inability to trace them need cause no discouragement. The handle of the Dipper is the tail of the bear; the bowl is the animal's hip; the ears are at the little group marked Rho (ρ) and Sigma (σ); the nose is at Omicron (ο); the forefeet are at Iota (ι) and Kappa (κ); the hind feet at Lambda (λ) and at Xi (ξ).

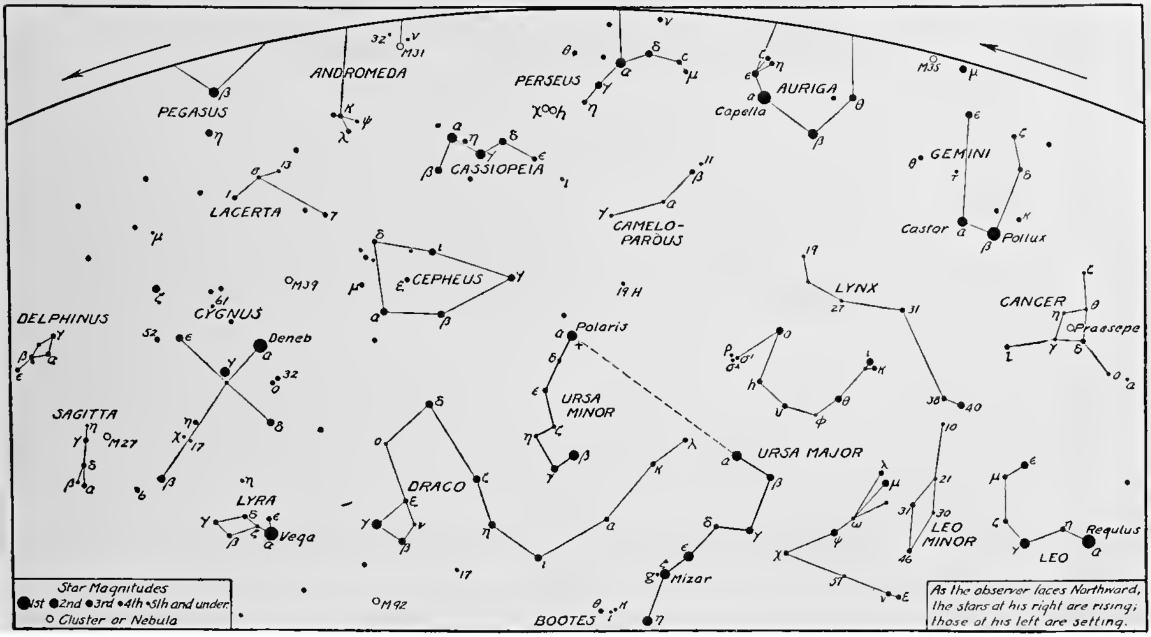
Let us again follow with our eyes the line from the Pointers (α and β) in the Great Dipper to the Pole-star; and let us imagine that we are continuing this line in the same direction right on across the northern sky. Just above this continued line, quite high up, you will see the W-shaped figure which represents the chair of CASSIOPEIA [80]. Just below, you will see the fainter stars of CEPHEUS [100] making a sort of house-shaped figure with roof now pointing to the east.

Below the group just mentioned we may see the head of DRACO, the DRAGON [160], formed by the stars Gamma (γ), Beta (β), Nu (ν), and Xi (ξ). To the west of DRACO, or toward the left, we may note CYGNUS, the SWAN [145]. The stars DENEB [146] etc., form, as you will see, the figure of the Northern Cross, or, if we wish to find in the same stars the figure of the flying swan, the head will be at Beta (β), the tail at Alpha (α), and the tips of the wings at Delta (δ) and Epsilon (ε). To the left of CYGNUS and quite to the west you will see DELPHINUS, the DOLPHIN [155], with its pretty diamond-shaped figure; and, below, you will note SAGITTA, the ARROW [335].

Below CYGNUS and the Cross and to the right you will find the small but important constellation, LYRA, or the LYRE [260]. These stars will soon be setting. The star VEGA [261], bluish white, is one of the brightest in the sky. LYRA can always be identified by the four-sided figure of the small stars Delta (δ), Gamma (γ), Beta (β), and Zeta (ζ). Toward a point in space quite near to VEGA our Sun, see p. 66, is moving at the rate of more than 720 miles a minute, taking with him the earth and all the planets of our solar system. So vast, however, are the distances of space that only an infinitesimal fraction of the journey is traversed in a century of time.

As VEGA sets, you will see far toward your right, at the north-east and very low down, the first stars of LEO, the LION [225], rising. You may have to wait a few minutes ere you can make them out. Of these stars, forming—as you see—a figure like a sickle, the brightest is REGULUS [226]. Above REGULUS are the faint stars of CANCER [50], the CRAB; and the brighter stars of GEMINI [185], the TWINS, shown more fully in our next map. Of LEO we will speak again when the whole constellation is higher up and in better position for observation; see p. 44. The stars here shown lead the way, however, and the figure of the sickle serves as a convenient sign of identification.

The stars of CANCER are not bright, and on dull nights they are not easy to find except with an opera-glass or field-glass. But on a very clear evening the pretty star cluster called PRAESEPE or the BEE-HIVE [52], can be recognized like a tiny patch of cloud, even with the unaided eye. A telescope of low power will show the twinkling of its many suns.




KEY-MAP TO THE SKY AS THE OBSERVER FACES NORTH.
JAN. 1, 8 P.M., DEC. 15, 9 P.M., DEC. 1, 10 P.M., NOV. 15, 11 P.M., NOV. 1, 12 P.M.
FOR NIGHT-CHART TO THIS MAP SEE OPPOSITE PAGE.
FOR THE SKY AS THE OBSERVER FACES SOUTH, SEE PP. 40, 41.
For the sky at other Dates and Hours see Time Schedule, p. 35.

**The Telescopic Objects. For the Constellations See the Page Opposite.**

Numbers in brackets [ ] refer to corresponding numbered notes in Observer's Catalogue, p. 116.

I. For opera-glass and field-glass there are fine star-fields through Cassiopeia [80] and Cygnus [145]. Here lie some of the richest sections of the Galaxy or Milky Way (see p. 19). We can see that it is made up of innumerable stars closely massed together.

In Lyra [260] the star marked Epsilon (ε) can, with opera-glass or field-glass, be seen as double. In a telescope 3¼ in. or over, it will be found a quadruple, or double-double [263]. In Cygnus almost on a line between Alpha (α) and Delta (δ) there are two neighbor stars marked Omicron (ο) [148] making—with the star *32* [149]—the centre of a pretty field. Near the foot of the cross the little star marked *6*—though in another constellation—is an easy double for a field-glass [426].

A field-glass, steadily held, will also divide the stars marked Delta (δ) and Zeta (ζ) [266, 265] in Lyra, and Nu (ν) in the head of Draco [162]. Note with the opera-glass the little star marked *g* near Mizar [401] in the Great Dipper. Its name is Alcor [402]. Mizar and Alcor together were called by the Arabs "the horse and his rider."

II. With a two-inch telescope the star-fields of Cygnus and Cassiopeia are even more interesting than with a field-glass. For these and all the other objects thus far noted use a low-power eyepiece. In addition to the above try Beta (β) [262] in Lyra, and also Beta (β) in Cygnus at the foot of the Cross, one of the finest objects within the range of a small instrument [147]. The colors of the components are orange and blue. Farther to the west a pretty double is also found in the Gamma (γ) of Delphinus [157].

Turning again to the north, we shall find more interesting still the star Mizar [401] to which we have already referred, in the bend of the Dipper's handle. In addition to the little star Alcor a two-inch telescope will show that Mizar is itself a double star, one component a brilliant white, the other a pale emerald. Another, fainter, star is also visible, so that with Alcor four objects appear in the field of the telescope.

In Cepheus note the easy doubles, Delta (δ) [101], Xi (ξ) [103], and Beta (β) [102]. The last is the most difficult. Toward the right and at the northeast, double stars for a two-inch glass will also be found in Cancer [50]. Try the stars Iota (ι) and Zeta (ζ) [53, 54]. A charming star-cluster will be found here in Praesepe [52] or the Bee-hive. It may be readily found by drawing an imaginary line from Castor to Pollux and continuing it downward. The sparkling "star-dust" of the cluster will be found slightly to the left of it.

III. With a three-inch telescope all the preceding objects are, of course, even more available. In addition to the preceding, the observer can now try to divide Polaris, the Pole-star [406], by using a magnifying power of 75 to 100. The companion is not very close; it is difficult to see only because of the disproportionate brightness of the larger component.

Other stars for a three-inch telescope are Mu (μ) [153] near Lacerta, and *61* [150] as well as *17* [152] and Chi (χ) [151] in Cygnus; Omicron (ο) [163] in Draco; Alpha (α) [261] and Eta (η) [264] in Lyra, though the former is difficult for the beginner; indeed a 3½ or 4-inch telescope may be necessary. To the extreme right, try the Gamma (γ) [227] of Leo—a much more satisfactory object. This star is a binary, the two components being in slow revolution about a common centre of gravity. Of the stars of Gemini we will speak on p. 41; and the objects in constellations above the Pole we will discuss when they are in better position for observation. Of the clusters, that in Cancer named Praesepe [52], and that marked M 39 [154] (found by an imaginary line from Beta (β) to Gamma (γ) in Cygnus, projected onward) make fine objects if viewed with a low-power eyepiece. There are also beautiful star-fields near the star Gamma (γ) in Cygnus and near the garnet star Mu (μ) [104] in the constellation Cepheus.

NIGHT-CHART TO THE SKY AS THE OBSERVER FACES SOUTH.
JAN. 1, 8 P.M., DEC. 15, 9 P.M., DEC. 1, 10 P.M., NOV. 15, 11 P.M., NOV. 1, 12 P.M.
FOR KEY-MAP TO THIS CHART SEE OPPOSITE PAGE.
FOR THE SKY AS THE OBSERVER FACES NORTH, SEE PP. 38, 39.
For the sky at other Dates and Hours see Time Schedule, p. 35.

**The Constellations. For the Telescopic Objects See the Page Opposite.**

Numbers in brackets [ ] refer to corresponding numbered notes in Observer's Catalogue, p. 116.

As we face directly south, the east is of course upon our left hand. The stars that are now moving round from east to south present a superb spectacle. In ORION [290] note first the two stars of the first magnitude, BETELGEUZE [291] and RIGEL [292].

The former marks the right shoulder of the giant huntsman: the latter his left knee. His head is at Lambda (λ) and the tip of his uplifted club at Nu (ν). The three bright stars Zeta (ζ), Epsilon (ε), and Delta (δ) mark his belt, from which his sword hangs downward with its tip at Theta (θ).

To the left of ORION lies the dim group MONOCEROS [270] or the UNICORN, so unimportant that the beginner may well omit it till other groups are learned. Higher up are the stars of GEMINI, the TWINS [185]. The heads are marked by CASTOR [186] and POLLUX [187], named from the devoted comrades of the ancient myth.

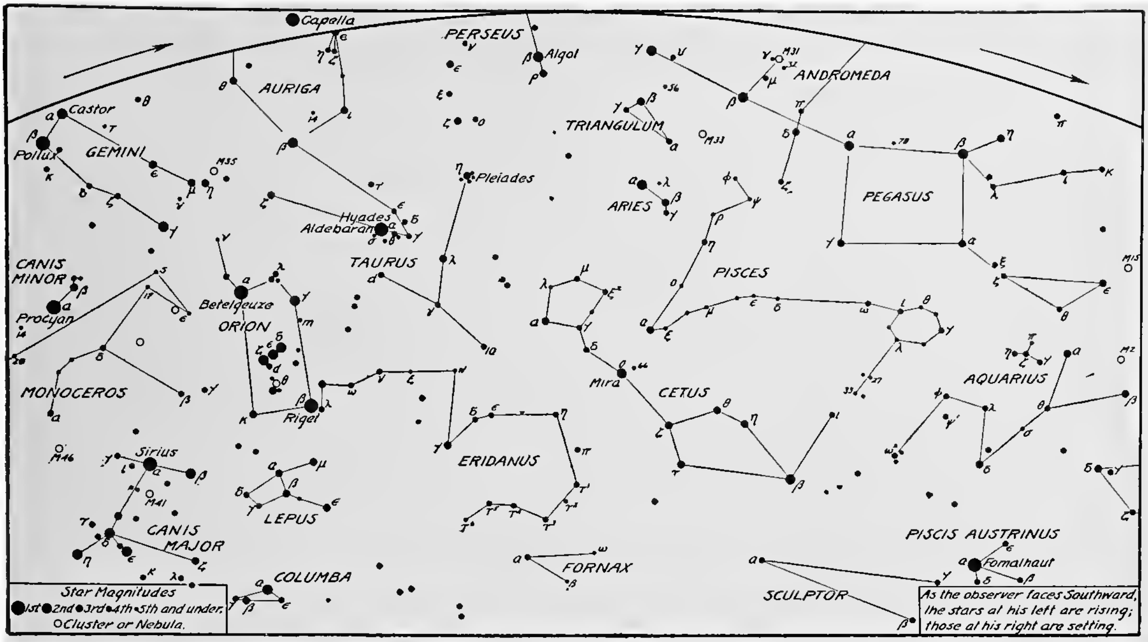
The three bright stars of ORION's belt, running diagonally through the oblong figure which marks his body, will point us upward toward the red star ALDEBARAN [381] and, still farther on, to the PLEIADES [382], the most beautiful of the star-clusters. Near ALDEBARAN is another cluster called the HYADES [383], not so thickly massed but almost as interesting. Both these clusters are in the constellation TAURUS, the BULL [380]. ALDEBARAN is the Bull's red eye, the nose is at Gamma (γ), the horns stretch away to Zeta (ζ) and Beta (β). The imaginary figure of the Bull, as with that of ORION, is incomplete.

Again taking our direction from the line of ORION's belt we find it pointing us in the other direction to SIRIUS [66], the brightest of all the stars,—supposed to mark the eye in the constellation, CANIS MAJOR, the GREAT DOG [65]. The dog sits upright with forepaws at Beta (β), ears at Gamma (γ) and his hind feet at Zeta (ζ). To the right of these stars and a little lower down is COLUMBA, the DOVE [125]; and a line from this group drawn through SIRIUS and carried onward will bring us to CANIS MINOR, the LITTLE DOG [70]. Its stars form no outline of a dog; but among them is PRÓCYON [71], a fine first-magnitude star.

To the right of SIRIUS and just below ORION are the stars of LEPUS, the HARE [240], and to the right of LEPUS stretches the long line of ERIDANUS [175], the RIVER, taking its rise near RIGEL. Returning now to TAURUS, we find that the triangular figure which has its apex at Gamma (γ) points us downward to the huge constellation of CETUS, the WHALE [110]. For MIRA, see p. 14. Above CETUS stretch the dim stars of PISCES, the FISHES [320], starting from the point at Alpha (α) and forming to the westward a pretty chaplet of small stars at Theta (θ), Lambda (λ), Gamma (γ), etc. Except on very clear nights some of these are not easily found without an opera-glass.

To the right of the PLEIADES lie the three bright stars that mark the small constellation of ARIES, the RAM [30]; and above ARIES shines the three-cornered figure of TRIANGULUM, the TRIANGLE [395]. Both groups are now too high for convenient study; but see p. 55.

In now looking to the right to the great square of PEGASUS, the WINGED HORSE [301], it will help us to assume that the upper corner of the map comes in toward us a little and that all the lines slant somewhat downward as indicated by the arrow in the corner; see p. 4. Far to the south-west, AQUARIUS, the WATER-BEARER [15], is setting, the mouth of the water-jar being marked by the little Y-shaped figure at Gamma (γ). Still further to the southward lies PISCIS AUSTRINUS, the SOUTHERN FISH [330], not to be confused with PISCES, the FISHES, to which we have just referred. The mouth of the Southern Fish is marked by FOMALHAUT [331], a star of the first magnitude. It is not so bright as SIRIUS or RIGEL but a welcome object in this vast region of less brilliant sky. It sets, in the latitude of New York, just as SIRIUS rises. In the latitude of London it sets a little earlier.




KEY-MAP TO THE SKY AS THE OBSERVER FACES SOUTH.
JAN. 1, 8 P.M., DEC. 15, 9 P.M., DEC. 1, 10 P.M., NOV. 15, 11 P.M., NOV. 1, 12 P.M.
FOR NIGHT-CHART TO THIS MAP SEE OPPOSITE PAGE.
FOR THE SKY AS THE OBSERVER FACES NORTH, SEE PP. 38, 39.
For the sky at other Dates and Hours see Time Schedule, p. 35.

**The Telescopic Objects. For the Constellations See the Page Opposite.**
Numbers in brackets [ ] refer to corresponding numbered notes in Observer's Catalogue, p. 116.

I. WITH OPERA-GLASS OR FIELD-GLASS examine the two star-clusters in TAURUS, the PLEIADES [382] and the HYADES [383]. The glass will greatly increase the charm and the interest of both groups; see p. 18. Near ALDEBARAN note the pretty doubles Theta (θ) and Sigma (σ) [386, 389], and below ORION another will be found in the Gamma (γ) of LEPUS [242].

A field-glass and sometimes even an opera-glass will reveal as a faint cloud of light, or misty radiance, the great nebula of ORION [294]. It enfolds the little star Theta (θ), just below ORION's belt. The existence of the star-cluster in CANIS MAJOR marked M 41 [67] and of that in GEMINI marked M 35 [188] can also be discerned, though here also a telescope is necessary for a really satisfactory view. To sweep with opera-glass or field-glass, however low its power, through this whole region of sky, especially through CANIS MAJOR, ORION, and TAURUS will bring rich returns of interest and pleasure. Except with optical aid the star MIRA [113] in CETUS is often quite invisible. It is strangely variable. See p. 14.

II. WITH A TWO-INCH TELESCOPE all the preceding objects are available, and the clusters mentioned take on new beauty. Using the eye-piece of lowest power, note the general aspect of the Orion nebula at the star Theta (θ) [294]. Then with a higher power, 65 or 70, study carefully the star itself. It is a quadruple, two of the components being reddish in color, one a pale lilac, and one white. Easy doubles will also be found in Delta (δ) [293], the top star of the belt, and in *m* [295] just above. Sigma (σ) [299] just below the lowest star of the belt will appear as a triple.

In GEMINI the most impressive double star is CASTOR [186], but Zeta (ζ) [193] and Delta (δ) [190] are also worthy of note. The latter may prove a little difficult for the beginnner. In TAURUS interesting objects will be found in Tau (τ) [387], and in Eta (η) [384], the brightest star of the PLEIADES; but these are high for present observation. There is also an easy double quite near the star marked (*10*) [388]. In MONOCEROS note the pretty triple star marked Beta (β) [271] called by Sir William Herschel "one of the most beautiful objects in the heavens." The beginner may be able to see only two of the components. Try Epsilon (ε) [272] in the same constellation and the star marked *w* in ERIDANUS [176]. Easier doubles will be found in the Lambda (λ) [31] and Gamma (γ) [32] of ARIES, both stars being of special importance.

III. WITH A THREE-INCH TELESCOPE first try the objects mentioned for the two-inch, using a low-power eye-piece and giving special attention to the great nebula in ORION [294] and the star-clusters already specified.

In ORION try Lambda (λ) [300], just above and to the right of BETELGEUZE; two stars [297] below Theta (θ); and Zeta (ζ) [296], the lowest star of the belt. The latter is a triple but the beginner may not at first see more than two of the components. RIGEL [292] is a superb double, the small blue companion being an exacting test even under fine atmospheric conditions. Easier objects for a three-inch instrument are the Kappa (κ) [189], Epsilon (ε) [191] and Nu (ν) [194] of GEMINI. In PISCES, a fine double star will be found in Alpha (α) [321]; and a fainter but pretty object in Psi (ψ) [323].

A low-power eye-piece will show the small blue companion to Alpha (α) [111] in CETUS; and, with an eye-piece of higher power, other interesting doubles in CETUS will be found in the stars Gamma (γ) [112]; *66* [116] and Zeta (ζ) [114]. Farther to the west, in AQUARIUS, note another Zeta (ζ) [17], the star at the centre of the little Y which marks the mouth of the water-jar. It is an extremely pretty double, the components being almost equal in magnitude.

In this map the track of the planets lies through the constellations AQUARIUS, PISCES, ARIES, TAURUS, and GEMINI. The approximate positions of the planets as they move through the stars may be easily found for any month, from the tables on pp. 84, 86, etc.

NIGHT-CHART TO THE SKY AS THE OBSERVER FACES NORTH.
MARCH 1, 8 P.M., FEB. 15, 9 P.M., FEB. 1, 10 P.M., JAN. 15, 11 P.M., JAN. 1, 12 P.M.
FOR KEY-MAP TO THIS CHART SEE OPPOSITE PAGE.
FOR THE SKY AS THE OBSERVER FACES SOUTH, SEE PP. 44, 45.
For the sky at other Dates and Hours see Time Schedule, p. 35.

**The Constellations. For the Telescopic Objects See the Page Opposite.**

Numbers in brackets [ ] refer to corresponding numbered notes in Observer's Catalogue, p. 116.

We now find that the Great Dipper, in its revolution round the Pole (see p. 23), is moving from position B and is on its way toward position C. The "pointers," the stars Alpha (α) and Beta (β) in the Dipper's bowl, will direct us to POLARIS, or the Pole-Star [406]. This, as we have seen, is at the tip of the handle of the Little Dipper. These stars are part of the constellation called URSA MINOR [405], or the LITTLE BEAR. We have already shown, p. 38, how the Great Dipper is part of the GREAT BEAR, or URSA MAJOR [400].

On the other side of the pole from the Great Dipper, and at about the same distance from POLARIS, are the stars of CASSIOPEIA, or the LADY OF THE CHAIR [80]; they form a figure like a large W, much spread out. Above this striking group shine the stars of PERSEUS [305]; and higher still are those of AURIGA, the CHARIOTEER [35], but at present these are rather high up for convenient observation. CAPELLA [36] is a star of the first magnitude.

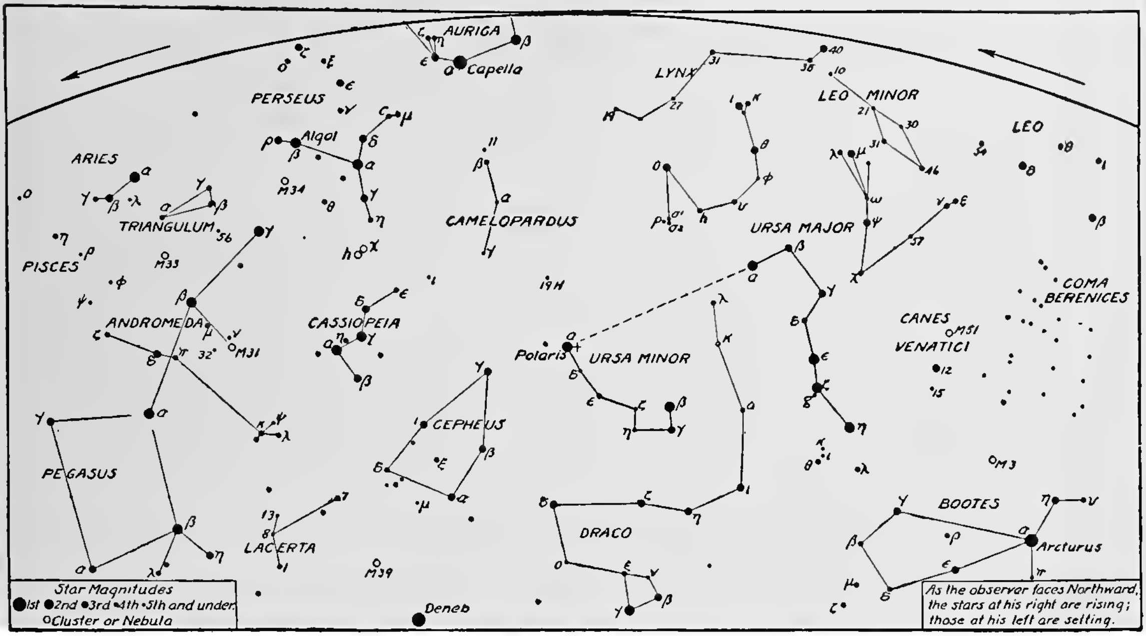
The brightest star in PERSEUS, that marked Alpha (α), is not far from the famous variable, ALGOL [307], of which we have spoken at length on p. 13. These two stars form a right-angled triangle with the Gamma (γ) [3] of ANDROMEDA just below. Farther to the west lie the stars of TRIANGULUM, the TRIANGLE [395], and of ARIES, the RAM [30]. In the former is found the beautiful nebula illustrated on p. 36. ARIES lies in the track of the planets. The line in ARIES from Alpha (α) to Beta (β) is now more nearly perpendicular to the horizon than can be shown at this corner of the map, and the TRIANGLE points more nearly downward (see note 7, p. 31).

Of ANDROMEDA [1] and PEGASUS [301] we will speak again when these constellations are rising, p. 54. We can see here, however, that the great square of PEGASUS is indebted to ANDROMEDA for one of its corner stars. To the eye, the Alpha (α) of PERSEUS seems like a continuation of the long line of PEGASUS and ANDROMEDA, it being the fifth and last in a bold series of almost equidistant second-magnitude stars. The star Beta (β) in PEGASUS is now very low down, but before it sets we may note that the imaginary line from Beta (β) to Alpha (α) in the Dipper, if continued onward across the sky, will come very near to this corner in the square.

We have already spoken of the stars of CEPHEUS [100]; of DENEB [146], the brightest star of the Northern Cross; and of DRACO [160], the DRAGON; see p. 38; but to the right and at the northeast some new groups are rising above the horizon. Very low down is the constellation called BOÖTES, the HERDSMAN [40]. Its leading star, the superb ARCTURUS [41], may be identified by its reddish yellow light. Moreover, we may note that if we continue the sweep of the circle rudely represented by the handle of the Great Dipper, we shall find the handle pointing us to ARCTURUS, just as the handle of the Little Dipper will always point us in the general direction of CAPELLA [36]. We speak more fully of AURIGA [35] when more conveniently placed; p. 46.

Just above BOÖTES at this hour, a little to the left, are a few faint stars, two among them marked *12* and *15*, which represent the constellation CANES VENATICI, the HUNTING DOGS [60]. They make no outline of such figures, but the dogs which they symbolize are supposed to be running before the HERDSMAN as he drives the GREAT BEAR, URSA MAJOR, around the Pole. We may suppose ARCTURUS to be in the Herdsman's belt; and we may imagine his head to be at Beta (β), his shoulders at Delta (δ) and Gamma (γ), his extended knee—as he runs—at Eta (η). But the figure has been drawn in many different ways.

Above the HERDSMAN, and to the right from the Great Dipper, is the scattered cluster of small stars called COMA BERENICES, or BERENICE'S HAIR. For the myth associated with this group, see the Observer's Catalogue, under its reference number [120]. We will speak of LEO [225] on p. 44, as we look southward.




**KEY-MAP TO THE SKY AS THE OBSERVER FACES NORTH.**

**MARCH 1, 8 P.M., FEB. 15, 9 P.M., FEB. 1, 10 P.M., JAN. 15, 11 P.M., JAN. 1, 12 P.M.**

FOR NIGHT-CHART TO THIS MAP SEE OPPOSITE PAGE.

FOR THE SKY AS THE OBSERVER FACES SOUTH, SEE PP. 44, 45.

For the sky at other Dates and Hours see Time Schedule, p. 35.

## The Telescopic Objects. For the Constellations See the Page Opposite.

Numbers in brackets [ ] refer to corresponding numbered notes in Observer's Catalogue, p. 116.

I. FOR OPERA-GLASS AND FIELD-GLASS the rich regions of PERSEUS [305] and CASSIOPEIA [80] present views of great interest and beauty. These constellations lie in the Milky Way, and, if the night be clear, they will well reward the student. Observe especially the superb field of stars near Alpha (α) in PERSEUS. Note also the "sword-handle" of the hero, composed of the great double cluster marked *h*-χ [309] in our map. It is almost on a line connecting the star Eta (η) in PERSEUS with Epsilon (ε) in CASSIOPEIA. Its appearance in a large telescope is shown by the illustration on p. 5.

The existence of the great nebula in ANDROMEDA may be discerned, also, but it is not so interesting in a small instrument. It forms an irregular triangle with the little stars *32* and Nu (ν), and is marked M 31 [2]. To the eastward, or to the right of the Great Dipper, the opera-glass and field-glass may be well employed among the stars of COMA BERENICES [120], or BERENICE'S HAIR. Among the double stars for opera-glass or field-glass, steadily held, are Delta (δ) in CEPHEUS [101], Nu (ν) [162] in the head of DRACO, and *15* [62] in CANES VENATICI. Note also the stars Zeta (ζ) [401] and *g* [402] at the bend of the Dipper's handle. These are MIZAR and ALCOR, "the horse and his rider."

II. FOR THE TWO-INCH TELESCOPE there are, first of all, the objects just specified. The very lowest available power should, of course, be used, in order that the instrument may show a broad field, with the largest possible amount of light. A somewhat higher power should be employed on double stars. Of objects of this kind the star Zeta (ζ) [401] at the bend in the Dipper's handle, is one of the finest. Another beautiful double for a two-inch telescope will be found to the Dipper's right,—the star marked *12* [61] in CANES VENATICI. It was named "COR CAROLI" in honor of Charles II. Near the tip of the Dipper's handle, below and to the left, is a group of little stars belonging to BOÖTES, two of which, Kappa (κ) and Iota (ι) [45, 46] are easy doubles. Such are also Delta (δ) [43] and Pi (π) [44] of the same constellation, though we may wish to wait till they are a little higher in the sky. We may next observe the even easier double star Nu (ν) [162] in the head of DRACO; and the stars Delta (δ) [101], Xi (ξ) [103], and Beta (β) [102] in CEPHEUS. The last is the most difficult of the three. The Gamma (γ) [3] of ANDROMEDA is one of the most beautiful objects within the range of a two-inch instrument. Still further to the westward fine objects will also be found in the Lambda (λ) [31] and Gamma (γ) [32] of ARIES. On a line through the Gamma (γ) of TRIANGULUM to Beta (β) and continued onward, is a little star, belonging to ANDROMEDA, marked *56* [5]. It is a wide double. On a line upward from Gamma (γ) in ANDROMEDA to the Beta (β) of PERSEUS lies a fine star cluster marked M 34 [311]. The nebula M 33 [396] is not far distant.

III. WITH A THREE-INCH TELESCOPE all the preceding objects, both for the field-glass and for smaller telescopes, may well be studied before proceeding further. Many of them are important objects for telescopes of any size, however large. POLARIS, the Pole-Star [406], is always an interesting object. The small blue companion will now be found slightly upward to the right of the larger star. One of the most beautiful of the binary systems is represented by Eta (η) [82] in CASSIOPEIA. The contrast in colors is very marked. As the components are quite near together for a three-inch with average powers, much care should be taken to ensure the steadiness of the instrument. Iota (ι) [83] in the same group should be tried also, as well as the stars Omicron (ο) [163], Delta (δ) [166], and Iota (ι) [164] in DRACO. Gamma (γ) [165], in DRACO'S head, is a little more difficult. At the time covered by our next map of the northern sky, these stars will be in better position for observation. Eta (η) [308] in PERSEUS should be noted, and special attention given to the famous double cluster [309] just below.

NIGHT-CHART TO THE SKY AS THE OBSERVER FACES SOUTH.
MARCH 1, 8 P.M., FEB. 15, 9 P.M., FEB. 1, 10 P.M., JAN. 15, 11 P.M., JAN. 1, 12 P.M.
FOR KEY-MAP TO THIS CHART SEE OPPOSITE PAGE.
FOR THE SKY AS THE OBSERVER FACES NORTH, SEE PP. 42, 43.
For the sky at other Dates and Hours see Time Schedule, p. 35.

**The Constellations. For the Telescopic Objects See the Page Opposite.**
Numbers in brackets [ ] refer to corresponding numbered notes in Observer's Catalogue, p. 116.

Looking southward, we find that the constellations—Taurus, Orion, Canis Major—so conspicuous in our last map of the southern sky, have moved farther to the west, or toward the right. But these groups are so brilliant that they dominate the scene here just as they did in our study of them on p. 40.

Canis Major, or the Great Dog [65], is before us directly to the south. A line through this group, from the star marked Delta (δ), up through Sirius [66], the brightest star of the sky, will point almost directly to Betelgeuze [291], the fine reddish star in the right shoulder of Orion [290]. Under the map on p. 40 we have pointed out how the stars of these two groups were supposed to suggest the likeness of the Great Dog, and the Giant Hunter. If we continue the imaginary line from Sirius to Betelgeuze, and carry it onward, it will cross the horns of Taurus, the Bull [380], which is supposed to be charging down upon Orion, his fiery red eye being at the star Aldeb'aran [381] and the tips of his horns at Zeta (ζ) and Beta (β).

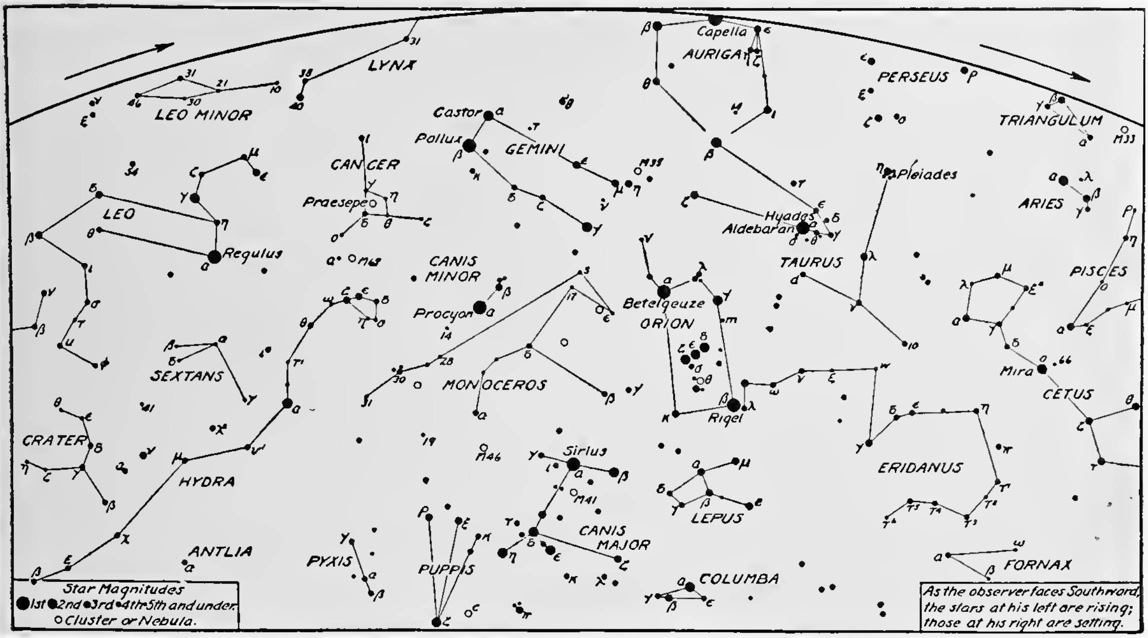
High above these stars is Capella [36], the splendid first-magnitude star of Auriga, the Charioteer [35], and lower down, to the westward, are the Pleiades [382]. Near Aldeb'aran shines the more scattered cluster called the Hyades [383]. The lower horn of Taurus points eastward to Gemini, the Twins [185], with its pair of bright stars called Castor [186] and Pollux [187]. The former is of the second, the latter of the first magnitude.

These two stars are very high up, but almost directly below them to the south is Pro'cyon [71], a fine first-magnitude star, belonging to the small constellation Canis Minor, the Little Dog [70]. A line downward from Pro'cyon to Sirius and carried onward, will bring us quite near to the little group called Columba, the Dove [125]. Above this small constellation and between it and Orion, lies Lepus, the Hare [240]. From Orion westward flows the faint current of Erid'anus, the River [175]; and still farther west is Cetus, the Whale [110], part of which has already set. Northward from Cetus lie Pisces [320] and Aries [30], though the former is too near the horizon to be well seen. The distortion in the drawing, inevitable at the edges of any widely extended star-map, should here be borne in mind. The line from Alpha (α) to Beta (β) in Aries runs more directly downward in the sky than here shown.

Just as the lines in the constellation figures far westward, or on the right, slant downward, so the lines to the eastward, at the left, slant upward. For example, in Leo, the Lion [225], the well known "sickle" leads the way, the star Regulus [226] now appearing higher in the sky than the star Beta (β) [229]. Three or four hours later, however, a line connecting them will seem much more nearly parallel to the horizon, see p. 49. Regulus has represented the Lion's heart, his head being in the "sickle," and his tail at Beta (β).

Just westward from Leo lie the faint stars of Cancer, the Crab [50], and directly below Cancer lies the head of Hydra, the Water-Snake [210], the most extended of the constellations. Hydra, like Draco at the north, is not at first easily distinguished, but, when its stars are once recognized, it becomes interesting to follow their clear and winding course. Alphard, the star in Hydra marked Alpha (α) [211], is sometimes called "Cor Hydræ" or the Serpent's Heart. It is a fine object in a region large but singularly dull. Crater, the Cup [140], is sometimes counted as a part of Hydra, but neither it nor Sextans, the Sextant [375], is brilliant or important.

Between Hydra and Orion lies the dim constellation, Monoceros, the Unicorn [270]. Below these faint stars and east of Canis Major lie the stars of Puppis and Pyxis, parts of the Ship Argo (Argo Navis) [25]. This is a large and brilliant constellation, but too far south for us to have more than a peep at it "over the edge of the world."




KEY-MAP TO THE SKY AS THE OBSERVER FACES SOUTH.
MARCH 1, 8 P.M., FEB. 15, 9 P.M., FEB. 1, 10 P.M., JAN. 15, 11 P.M., JAN. 1, 12 P.M.
FOR NIGHT-CHART TO THIS MAP SEE OPPOSITE PAGE.
FOR THE SKY AS THE OBSERVER FACES NORTH, SEE PP. 42, 43.
For the sky at other Dates and Hours see Time Schedule, p. 35.

**The Telescopic Objects. For the Constellations See the Page Opposite.**

Numbers in brackets [ ] refer to corresponding numbered notes in Observer's Catalogue, p. 116.

I. FOR THE OPERA-GLASS AND FIELD-GLASS there are rich star-fields through CANIS MAJOR, ORION, and TAURUS. The region of the little star marked Theta (θ) in ORION is especially beautiful, for on a clear night—particularly if there be no moon—something may be seen of the great nebula [294].

In TAURUS, there are fine objects in the scattered star-cluster called the HYADES [383], near the bright star ALDEB'ARAN [381], and in the closer and more brilliant cluster called the PLEIADES [382]. We may also gain a glimpse of the cluster in GEMINI marked M 35 [188], that in CANIS MAJOR marked M 41 [67], and that in CANCER marked PRÆSEPE [52], the last being the most interesting of the three. Note also the double stars, Gamma (γ) [242] in LEPUS, and Theta (θ) [386] and Sigma (σ) [389] in TAURUS. Observe also the little "neighbor" stars near Alpha (α) [226] and Gamma (γ) [227] in LEO. Their connection is probably optical, see p. 13, rather than real.

II. FOR A TWO-INCH TELESCOPE, there are, first, the objects already noted. The clusters, if viewed with a low-power eye-piece, are not only easy to find but especially beautiful. To these may be added M 67 [55], just above the head of HYDRA and to the right of the little star marked Alpha (α) in CANCER. In studying the great nebula in ORION, remember to view the region first with the lowest available power,—then use an eye-piece of higher power on the star Theta (θ) itself [294]. Among the double stars of ORION, note Delta (δ) [293], the uppermost star in the belt, and *m* [295], just above. Sigma (σ) [299], below, appears as a fine triple.

In MONOCEROS there are good objects in Beta (β) [271] and Epsilon (ε) [272]; and, among the double stars of GEMINI, in Zeta (ζ) [193], Delta (δ) [190], and CASTOR [186], though the latter are now rather high up for convenient study. LEO, however, is better placed for observation, and in Gamma (γ) [227] we have one of the most beautiful of the binary systems. The two components are in slow motion about a common center of gravity. The beginner should here use a power, on a two-inch instrument, of about 75; nor need there be discouragement if the division between the stars is not detected in a first attempt. Tau (τ) [228], in the same constellation, is not so easily found, but much more easily divided. Far to the westward, fine and yet easy objects will be found in the Lambda (λ) [31] and Gamma (γ) [32] of ARIES. Note also the Tau (τ) [387] and the Eta (η) [384] of TAURUS; the double near the star marked *10* [388] in the same constellation; and—below it in ERID'ANUS—that marked *w* [176].

III. WITH A THREE-INCH TELESCOPE examine, first, the preceding objects. Give special attention to CASTOR [186]; to Gamma (γ) in LEO [227]; and to Theta (θ) [294] in ORION, with the great nebula which attends it. All the objects mentioned for the field-glass or the two-inch telescope are even better subjects for the three-inch.

In ORION use a higher power in viewing Lambda (λ) [300] in the giant's head, and Zeta (ζ) [296], the lowest star of the belt. Beneath Theta (θ) will be found Iota (ι) [297]—the brightest of the unmarked stars touching the little circle which marks the nebula. Just to the right, is another unmarked double—see [297] in the Observer's Catalogue. RIGEL [292], lower to the right, is a difficult but noble object.

In GEMINI are also the double stars Kappa (κ) [189], Epsilon (ε) [191], and Nu (ν) [194]; and in CANCER, Iota (ι) [53] and Zeta (ζ) [54]. In LEO, the star marked Beta (β) [229] may be tried; as well as Alpha (α) [211] and Epsilon (ε) [212] in HYDRA; and Alpha (α) [241] in LEPUS; but these four are difficult except in an instrument a little larger than three inches. In MONOCEROS fine objects will be found in the cluster to the left of Epsilon (ε) and in that to the right of Delta (δ); see [274] and [273]. In our present map the track of the planets lies through PISCES, ARIES, TAURUS, GEMINI, CANCER, and LEO. See p. 80.

NIGHT-CHART TO THE SKY AS THE OBSERVER FACES NORTH.
MAY 1, 8 P.M., APRIL 15, 9 P.M., APRIL 1, 10 P.M., MARCH 15, 11 P.M., MARCH 1, 12 P.M.

FOR KEY-MAP TO THIS CHART SEE OPPOSITE PAGE.
FOR THE SKY AS THE OBSERVER FACES SOUTH, SEE PP. 48, 49.
For the sky at other Dates and Hours see Time Schedule, p. 35.

**The Constellations. For the Telescopic Objects See the Page Opposite.**

Numbers in brackets [ ] refer to corresponding numbered notes in Observer's Catalogue, p. 116.

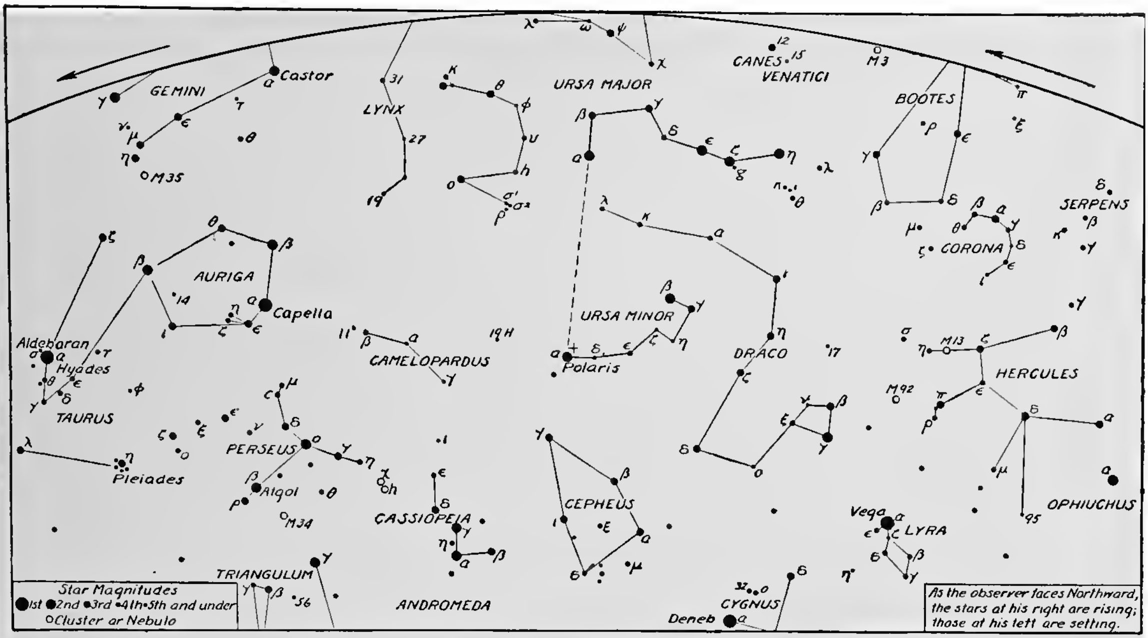
We may see, in turning to our diagram on p. 23, that the Great Dipper has now moved nearly to position C in its revolution round the Pole. CEPHEUS and CASSIOPEIA are still, of course, on the other side of the Pole from the Dipper, for they have been moving round below the Pole while URSA MAJOR or the GREAT BEAR [400], of which the Dipper is a part, has been reaching its "upper culmination."

The stars of CEPHEUS [100] are so faint that the house-shaped figure is not always clearly seen when so near the horizon; but CASSIOPEIA, the LADY OF THE CHAIR [80], while almost as low down, is gifted with brighter stars. As her head is supposed to be near Beta (β) and her feet at Epsilon (ε), her position just now is by no means comfortable. We may see that the W made by her stars is even clearer in the sky than in the map. In the heavens, the small stars confuse the outline less, and the spaces of the actual sky are greater. To our left from CASSIOPEIA are the brilliant fields of PERSEUS [305]. During the early evenings of Summer, both constellations swing beneath the Pole and are so near the horizon that they are often obscured by mists; they are high above the Pole in the early evenings of Winter; see p. 58.

Still further westward are the stars of TAURUS, the BULL [380], with the PLEIADES [382] and HYADES [383], the two beautiful star-clusters of this constellation; while northward from TAURUS and just above PERSEUS is AURIGA, the CHARIOTEER [35], containing CAPELLA [36], one of the finest of the first-magnitude stars. We may note quite near CAPELLA, or the GOAT, the three little stars called the Kids. They are Epsilon (ε), Eta (η), and Zeta (ζ); and their presence always establishes the identity of CAPELLA among the stars. AURIGA is supposed to be holding CAPELLA and her Kids in his arms. Above, shine the stars of GEMINI, the TWINS [185], of which we will speak again as we face southward.

Turning directly toward POLARIS, or the Pole-Star, we see that the Little Dipper of URSA MINOR, the LITTLE BEAR [405], is turned upward, just as the Great Dipper of URSA MAJOR is turned downward. Between the two and winding eastward is the long constellation called DRACO, the DRAGON [160]. The head is formed by the stars Beta (β), Gamma (γ), etc. Wherever we see the head of DRACO we may know that HERCULES [200], his slayer, is not far distant. The figure of the hero in the stars is as difficult to decipher as in the case of PERSEUS —and our inability to "make it out" need not discourage us. See the Observer's Catalogue [200]. But to be able to recognize the constellation *as a group of stars* is important. The light lines from Delta (δ) to Nu (ν) and *95* are mere guide-lines for the telescope. Omit them in drawing the other lines of the constellation. First make clear note of the figure—somewhat like a "hopper" and sometimes called the Key-stone—made by the stars Pi (π), Epsilon (ε), Zeta (ζ), and Eta (η). It is by this figure that the group is most easily recognized in the sky. Then add to your mental picture, or to your drawing, the line Epsilon (ε), Delta (δ), Alpha (α); and then the line Zeta (ζ) to Beta (β). Do not confuse Alpha (α) with the brighter star just below it.

Above HERCULES shines a small but beautiful group called CORONA, the CROWN, or CORONA BOREALIS, the NORTHERN CROWN [130]. Below HERCULES rises LYRA, the LYRE [260], not only a fine group to the eye but of the deepest interest. VEGA [261], its leading star, may always be identified by the figure formed by the stars Beta (β), Gamma (γ), Delta (δ), Zeta (ζ); and by the further fact that just as the handle of the Little Dipper points in a general way toward CAPELLA, it also points, in its general direction, away from VEGA. It is a star of the first magnitude, bluish white in color, and its light is singularly penetrating. It is often seen long before the other stars appear. Much further information concerning this star will be found under its reference number [261] in the Observer's Catalogue.




KEY-MAP TO THE SKY AS THE OBSERVER FACES NORTH.

MAY 1, 8 P.M., APRIL 15, 9 P.M., APRIL 1, 10 P.M., MARCH 15, 11 P.M., MARCH 1, 12 P.M.

8, 7:30.
15, 7:00

FOR NIGHT-CHART TO THIS MAP SEE OPPOSITE PAGE.

FOR THE SKY AS THE OBSERVER FACES SOUTH, SEE PP. 48, 49.

For the sky at other Dates and Hours see Time Schedule, p. 35.

**The Telescopic Objects. For the Constellations See the Page Opposite.**

Numbers in brackets [ ] refer to corresponding numbered notes in Observer's Catalogue, p. 116.

I. For opera-glass and field-glass there are rich fields through the Milky Way, here stretching low down from north to west. Note especially the regions near Epsilon (ε) in Auriga, near Alpha (α) in Perseus, and near Gamma (γ) in Cassiopeia. Further still to westward there are charming views in the Hyades [383] near the red star Aldeb'aran, and in the Pleiades [382]. The names of the brighter stars in the Pleiades are given in the Observer's Catalogue. See also pp. 18, 19. They are now setting, but with the evenings of Autumn we shall find them again at the northeast.

Turning, now, to the eastward or to the right, we find some easy double stars. Among these are the Delta (δ) [101] of Cepheus; Nu (ν) [162] in the head of Draco; and Delta (δ) [266], Zeta (ζ) [265], and Epsilon (ε) [263] in Lyra. These can all be divided by a field-glass, steadily held. The last named star is the famous "double-double,"—for a telescope of three and one-quarter or three and one-half inches will show that each of its two components is itself a double. Above Lyra, note the star-cluster in Hercules marked M 13 [206]. An opera-glass will barely show its existence and a field-glass will show it only as a very small globular patch of mist. A telescope of two or three or four inches will show in increasing measure the real nature of the object; but a large instrument, six to eight inches in aperture, is necessary to illustrate the basis of Herschel's opinion that it contains at least 14,000 stars. An object as beautiful, and more within range of a good field-glass, is the double cluster, χ-*h* [309], in Perseus. Above Hercules let us note with the opera-glass the beautiful circlet of stars which form Corona [130].

II. With a two-inch telescope, using an eye-piece of low power, the preceding objects are even more interesting than in the field-glass. The finest double star for a two-inch instrument is Zeta (ζ) [401] in the bend of the Great Dipper's handle, but it is now inconveniently high. So also are the pretty doubles *12* and *15* [61, 62] in Canes Venatici. Well placed for observation, however, are such fine objects as the Beta (β) [102] and Xi (ξ) [103] in Cepheus; the Beta (β) in Lyra [262]; and the Delta (δ) [202] and Alpha (α) [201] in Hercules. The last will require an eye-piece of higher power, but it is an object of singular charm. Note also the Tau (τ) [387], Phi (φ), [391], and Eta (η), [384] of Taurus; and the Gamma (γ) [3] of Andromeda—though this beautiful object is almost too low; and try the star in Auriga marked *14* [38]. Also examine the cluster M 34 [311] in Perseus.

III. With a three-inch telescope, first observe the objects already specified for the field-glass and the two-inch. These are appropriate for any instrument, however large. Then attempt Polaris, or the Pole-Star [406]. The small blue companion is now—as viewed in an astronomical telescope—almost directly above the brighter component. With an eye-piece having a power of from 75 to 100, the night being clear, there will be little difficulty in seeing it. Vega [261], the beautiful first-magnitude star of Lyra, is an even more difficult double than the Pole-Star, for a telescope of three and one-quarter or three and one-half inches is usually necessary for its division.

Other and easier doubles for a three-inch are the stars marked Rho (ρ) [204], Mu (μ) [203], and *95* [205] in Hercules; Zeta (ζ) [131] in Corona; and Iota (ι) [164], Omicron (ο), [163], and Gamma (γ) [165] in Draco. The last may be too difficult. Try it, however, as well as the Eta (η) [264] in Lyra; the Eta (η) [308] and Zeta (ζ) [310] in Perseus; and the fine binary star Eta (η) [82] in Cassiopeia.

In addition to the clusters specified for the two-inch, there is the cluster between Hercules and Draco marked M 92 [207]. It is almost on a line between the stars Pi (π) in Hercules and Beta (β) in Draco. While not of such intrinsic interest as M 13 [206], it is almost as satisfactory an object in a three-inch instrument.

NIGHT-CHART TO THE SKY AS THE OBSERVER FACES SOUTH.

MAY 1, 8 P.M., APRIL 15, 9 P.M., APRIL 1, 10 P.M., MARCH 15, 11 P.M., MARCH 1, 12 P.M.

FOR KEY-MAP TO THIS CHART SEE OPPOSITE PAGE.
FOR THE SKY AS THE OBSERVER FACES NORTH, SEE PP. 46, 47.
For the sky at other Dates and Hours, see Time Schedule, p. 35.

**The Constellations. For the Telescopic Objects See the Page Opposite.**

Numbers in brackets [ ] refer to corresponding numbered notes in Observer's Catalogue, p. 116.

As we now face southward, we find the constellation LEO, the LION [225], directly before us. LEO is rather high at present, but the group is easily recognized from the figure of "the sickle," formed by the stars Alpha ($\alpha$) or REGULUS, and Eta ($\eta$), Gamma ($\gamma$), Zeta ($\zeta$), Mu ($\mu$), and Epsilon ($\epsilon$). REGULUS [226] is a first magnitude star, but as it lies in the track of the planets, see p. 80, it is sometimes outshone by the brightness of Jupiter, Mars, or Venus. Below LEO lies the small constellation SEXTANS, the SEXTANT [375], faint and unimportant; and, lower still, the stars of HYDRA, the WATER-SNAKE [210], stretch their long course almost to the eastern horizon.

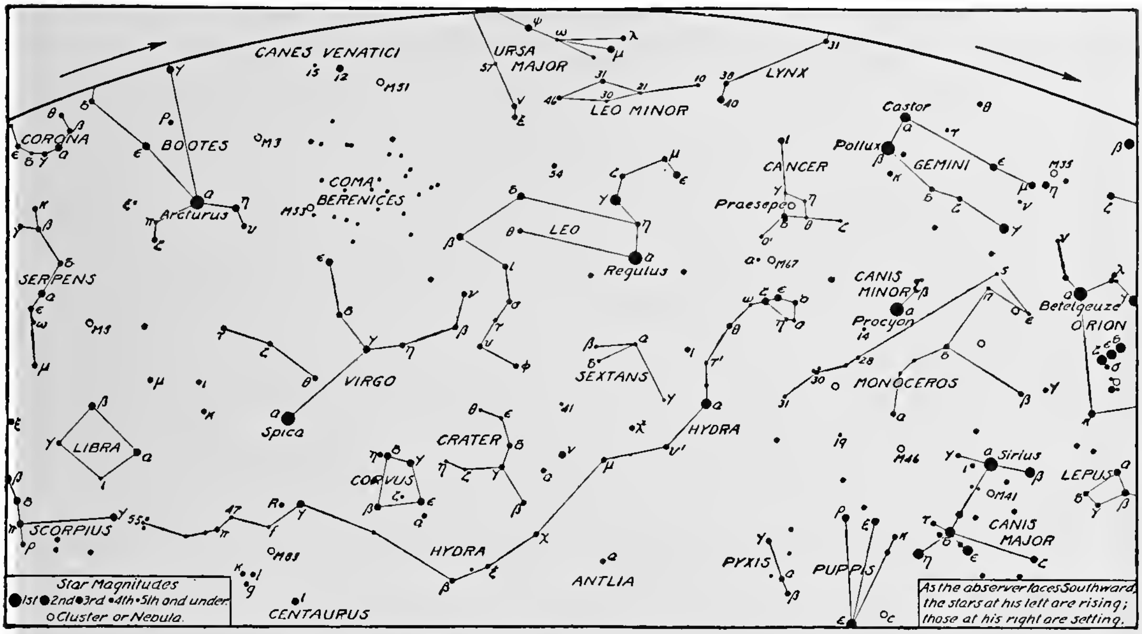
The faint stars of CRATER, the CUP [140], were at one time regarded as part of HYDRA, but they are now mapped separately. CORVUS, the CROW—or the RAVEN,—is more clearly seen and is more important [135]. From the diagram on p. 26 we have learned to associate CORVUS with the bright star SPICA [416], and to note how the line from Gamma ($\gamma$) to Delta ($\delta$) points to SPICA from every position and at every hour. Of all the first-magnitude stars SPICA is one of the whitest in color.

VIRGO [415], to which this star belongs, has represented a VIRGIN or MAID for untold centuries, among Chaldees, Egyptians, Greeks—and even among the Chinese. The figure is not clearly marked, the head being near Nu ($\nu$), the waist at Gamma ($\gamma$), the feet at Kappa ($\kappa$) and Mu ($\mu$), the right hand at Epsilon ($\epsilon$), and the left arm extended at the side, bearing a sheaf of wheat with its head at SPICA. To the left of VIRGO, and just rising, are the stars of LIBRA [245], the BALANCES or SCALES.

Above VIRGO and to the left of LEO are the masses of little stars—extremely pretty in an opera-glass—called COMA BERENICES or BERENICE'S HAIR [120]. To the west of LEO lie the faint stars of CANCER [50]. Next is the constellation GEMINI, the TWINS [185], its lines pointing more directly downward than can be here indicated in the map. CASTOR [186] and POLLUX [187] make one of the finest pairs in the sky, and not far away to the southwest is another pair, the first-magnitude star PRO'CYON and the neighboring Beta ($\beta$) in the small constellation called CANIS MINOR, the LITTLE DOG [70]. There is no danger of confusion, however, for in the latter pair the difference in brightness is marked. As ORION [290] sets, the uprightness of the figure here should be corrected by the figure of the group at position C on p. 25. CANIS MAJOR, the GREAT DOG [65], is also setting, as is LEPUS, the HARE [240], but all that we can discern of the former in latitudes as far north as New York, is the departing flash of the great SIRIUS [66].

Still facing south, but again turning eastward—to the left,—we may note the constellation BOÖTES, the HERDSMAN [40], distinguished for us by ARCTURUS [41], one of the noblest of the first-magnitude stars. The constellation forms a kite-like figure, and we have already indicated the mythical outline of the Herdsman, p. 42. It contains nothing else so interesting, however, as its brightest star, of which—under its reference number—we have spoken in the Observer's Catalogue. At the high velocity there indicated, ARCTURUS is rushing through space—according to Newcomb—toward the southwest, or in the general direction of the constellation VIRGO.

Before leaving this map, let us note what has sometimes been called "the Diamond of Virgo." It is formed by four stars. These are SPICA, ARCTURUS, the Beta ($\beta$) of LEO—called DENEB'OLA,—and the star in CANES VENATICI, the HUNTING DOGS, which bears the mark *12*. It is often called "Cor Caroli," the HEART of CHARLES [61], after Charles II. of England. The little constellation to which the last star belongs has never contained an outline of a Hunting Dog or of anything else, but the diamond-shaped figure just noted is strikingly beautiful and, when once recognized, is not easily forgotten. It may also be noted that a straight line across the sky is formed by the three bright stars SPICA, REGULUS, and POLLUX—almost equidistant.




**KEY-MAP TO THE SKY AS THE OBSERVER FACES SOUTH.**

**MAY 1, 8 P.M., APRIL 15, 9 P.M., APRIL 1, 10 P.M., MARCH 15, 11 P.M., MARCH 1, 12 P.M.**

FOR NIGHT-CHART TO THIS MAP SEE OPPOSITE PAGE.
FOR THE SKY AS THE OBSERVER FACES NORTH, SEE PP. 46, 47.
For the sky at other Dates and Hours see Time Schedule, p. 35.

**The Telescopic Objects. For the Constellations See the Page Opposite.**

Numbers in brackets [ ] refer to corresponding numbered notes in Observer's Catalogue, p. 116.

I. WITH OPERA-GLASS OR FIELD-GLASS examine, first, the region to the left, or east, of LEO covered by the constellation COMA BERENICES, — "Berenice's Hair." The mythical story connected with these little stars is told in the Observer's Catalogue [120]. The scene on a clear night, when there is no moonlight to outshine their twinkling, is full of charm.

The regions of ORION and CANIS MAJOR, at the extreme west, will repay us quite as well so long as these groups are in the sky. Here see column 1, pp. 40 and 41; but all the stars near this right-hand border are too near the horizon for satisfactory observation. The lines of GEMINI run much more directly downward than our map can indicate; as to ORION see p. 25. If we run a line, however, from CASTOR to POLLUX and continue it onward we shall find just to the left of this line the pretty cluster, in CANCER, called PRAESEPE, or the Bee-hive [52]. We may also find it by searching just before the "sickle" of LEO. It is practically on a line, from Beta (β) in LEO to Eta (η), projected onward an almost equal distance. Among the wide double stars that may be divided by a field-glass, steadily held, are Gamma (γ) [242] in LEPUS, just below ORION; Tau (τ) in LEO [228]; and Alpha (α) [246] in LIBRA.

II. WITH A TWO-INCH TELESCOPE, note first such star clusters as that marked M 41 [67] in CANIS MAJOR; that in GEMINI marked M 35 [188]; those marked merely with little circles in MONOCEROS near the stars *30* [275], and Delta (δ) [273], and Epsilon (ε) [274]; that marked M 53 [121] in COMA BERENICES. The easiest for a small instrument is, of course, PRAESEPE [52] in CANCER.

Among the double stars for a two-inch telescope, three superb objects are now available: CASTOR [186] in GEMINI; the star Gamma (γ) [417] in VIRGO; and Gamma (γ) [227] in the "sickle" of LEO. The last is the most difficult. There is a little "neighbor star," only connected optically with the pair, that should not be confused with the real companion of the primary star. The two components of the binary system are very close together in the field of a two-inch, and a good glass with a steady mounting is requisite for their division. CASTOR is also a superb object. Use for each of these stars a power of from 65 to 75. Gamma (γ) in VIRGO is an easier object, not requiring powers quite so high and therefore a more beautiful pair for the beginner.

Other double or multiple stars for the two-inch are Pi (π) [44] and Delta (δ) [43] in BOÖTES; Alpha (α) [246] in LIBRA; Delta (δ) [136] in CORVUS; Tau (τ) [228] in LEO; Iota (ι) [53] and Zeta (ζ) [54] in CANCER; Delta (δ) [190] and Zeta (ζ) [193] in GEMINI; Beta (β) [271] and Epsilon (ε) [272] in MONOCEROS, and *14* [72] in CANIS MINOR. The double stars further to the westward are noted on p. 45. They are here too near the horizon for satisfactory observation.

III. WITH A THREE-INCH TELESCOPE, first examine the preceding objects. Each is not only appropriate for a three-inch but it may be viewed in such an instrument under far better conditions. With eye-pieces of the same power the field of view will be larger and it will be illuminated more clearly and brightly. It is also easier, first using an eye-piece of low power, to find the objects specified. To the star-clusters just mentioned add M 46 [26], almost on a line projected from SIRIUS through the Gamma (γ) of CANIS MAJOR; and M 67 [55], between CANCER and the head of HYDRA. With eye-piece of lowest power sweep through the region of VIRGO just west of Epsilon (ε). This is a region of many nebulæ too faint in our small instruments for individual classification. Add to the double-stars Alpha (α) [416], Theta (θ) [418], and Tau (τ) [419] in VIRGO; Epsilon (ε) [191], Kappa (κ) [189], Nu (ν) [194], and Lambda (λ) [192] in GEMINI. The last is the unmarked star forming a small triangle with Delta (δ) and Zeta (ζ). Try, also, Epsilon (ε) [212] in HYDRA, and Beta (β) [229] in LEO. The track of the planets lies here through GEMINI, CANCER, LEO, VIRGO, and LIBRA; see p. 80.

NIGHT-CHART TO THE SKY AS THE OBSERVER FACES NORTH.
JULY 1, 8 P.M., JUNE 15, 9 P.M., JUNE 1, 10 P.M., MAY 15, 11 P.M., MAY 1, 12 P.M.
FOR KEY-MAP TO THIS CHART SEE OPPOSITE PAGE.
FOR THE SKY AS THE OBSERVER FACES SOUTH, SEE PP. 52, 53.
For the sky at other Dates and Hours see Time Schedule, p. 35.

**The Constellations. For the Telescopic Objects See the Page Opposite.**

The numbers in brackets [ ] refer to corresponding numbered notes in Observer's Catalogue, p. 116.

Looking northward, we now find the Great Dipper, part of the constellation URSA MAJOR [400], high up but slowly wheeling downward. The bowl precedes the handle; and as shown on p. 23, it has now passed through position C and is moving toward position D. The handle of the Dipper was supposed to represent the Bear's tail; the hip being at the Dipper's bowl, the hind feet at Mu (μ) and at Xi (ξ), the forefeet at Kappa (κ), the ears at the little stars Sigma (σ), etc., and the nose at Omicron (ο). The Bear now has his head downward, his back being toward the Pole. The stars really form no likeness to this animal or to any other.

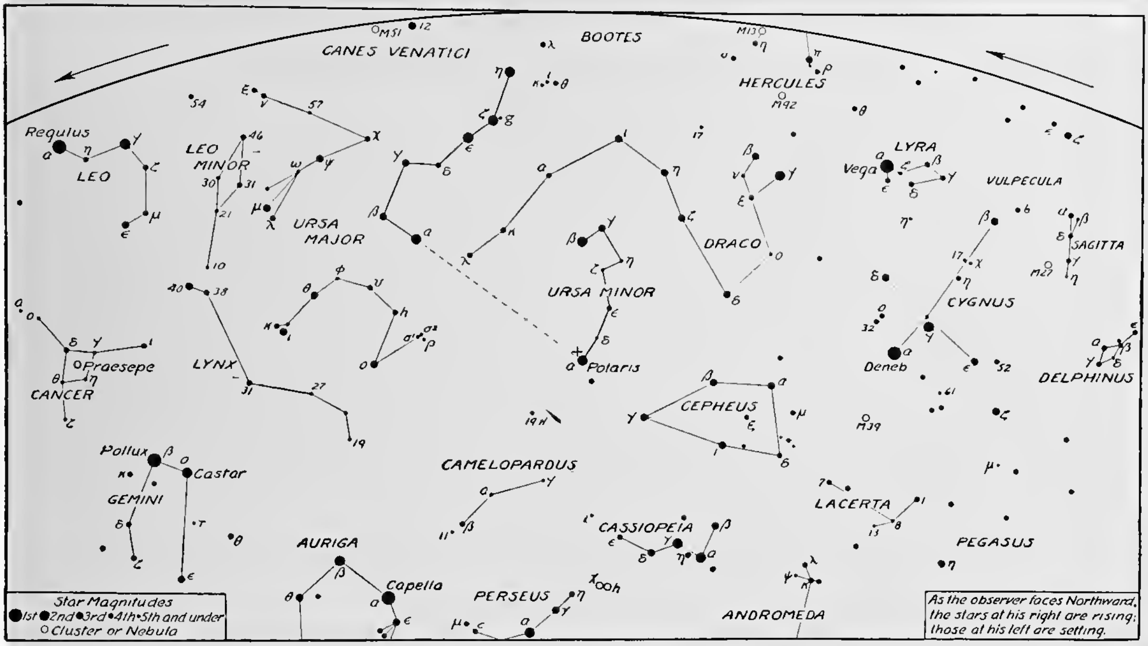
The line of direction to POLARIS, the Pole-Star, may be taken at every hour from the stars Alpha (α) and Beta (β) in the Great Dipper, and this line now points downward and toward the right. POLARIS [406] is at the tip of the handle of the Little Dipper, part of the constellation URSA MINOR, or the LITTLE BEAR [405]. If we continue this line straight on across the sky, it will pass between the house-shaped figure of CEPHEUS [100], and the brighter group called CASSIOPEIA [80], or THE LADY OF THE CHAIR. The line will cut through CEPHEUS not far from the star Gamma (γ), and, passing on, will "find" the star Beta (β) in PEGASUS [301] when it rises above the horizon; see p. 54. The line will traverse an unimportant group called LACERTA, the LIZARD [220]. The stars below this line are not high enough to be well seen, though the figure of the W, which represents the Chair of CASSIOPEIA, will doubtless be clearly marked. Above this line, however, lie three most interesting constellations.

First among these, let us note CYGNUS, the SWAN [145]. The head is supposed to be at Beta (β), the tips of the outstretched wings at Delta (δ) and Epsilon (ε), and the tail at Alpha (α) or DENEB [146]. These stars are more frequently regarded, however, as the Northern Cross; and when the figure is once recognized it is not easily forgotten. Eastward from CYGNUS, or further to the right, shines the small constellation called DELPHINUS, the DOLPHIN [155]. It presents no outline of a dolphin but four of its stars do form a very pretty diamond.

Turning more directly northward, and looking higher, we may see—above CYGNUS—the figure of LYRA, the LYRE [260], with its fine first-magnitude star VEGA [261]. Further to our left from VEGA we can detect the head of DRACO, the DRAGON [160], with the winding stars of this constellation looped, as it were, in a figure like an arch, above the bowl of the Little Dipper. The head of DRACO can always be found, when CYGNUS is in the sky, by the arms of the cross,—for a line drawn through them, from Epsilon (ε) to Delta (δ), will always point toward Gamma (γ), DRACO's brightest star. A line from this star to Beta (β) at the foot of the cross will point directly to the little constellation SAGITTA, the ARROW [335], lying, as does CYGNUS, full in the Milky Way.

Below the Pole, too far down for good observation, lie the fine constellations PERSEUS [305], and AURIGA, the CHARIOTEER [35]. CAPELLA [36], the beautiful first-magnitude star of the latter group, is so brilliant that it may often be seen through the mists of the horizon until almost the very moment of its setting. With Beta (β) of the same constellation, it forms a pair often mistaken for CASTOR and POLLUX, the companion stars of GEMINI, the TWINS [185]. These are now further to the westward. It should be noted, however, that the latter stars are nearer together—with the brighter above; not below, as in the case of the two bright stars of AURIGA.

The dim stars of CANCER [50] can hardly be seen so near the horizon, but above them shines the "sickle" of LEO [225]. This is not turned down quite so far as shown here, nor is it turned up quite so far as shown in the next map, p. 53, but the sickle does lead the way downward, the other lines of the figure stretching backward and upward from it. LYNX [255], and LEO MINOR [235], the LITTLE LION, are not important.




**KEY-MAP TO THE SKY AS THE OBSERVER FACES NORTH.**

**JULY 1, 8 P.M., JUNE 15, 9 P.M., JUNE 1, 10 P.M., MAY 15, 11 P.M., MAY 1, 12 P.M.**

FOR NIGHT-CHART TO THIS MAP SEE OPPOSITE PAGE.
FOR THE SKY AS THE OBSERVER FACES SOUTH, SEE PP. 52, 53.
For the sky at other Dates and Hours see Time Schedule, p. 35.

### The Telescopic Objects. For the Constellations See the Page Opposite.

The numbers in brackets [ ] refer to corresponding numbered notes in Observer's Catalogue, p. 116.

I. WITH OPERA-GLASS OR FIELD-GLASS follow, first, the course of the Milky Way as it stretches through AURIGA, PERSEUS, CASSIOPEIA, and on through CEPHEUS, CYGNUS, and SAGITTA. The innumerable stars which compose it are massed more thickly at some points than at others. Near Alpha (α) in PERSEUS, Gamma (γ) in CASSIOPEIA, and along the line of the Cross in CYGNUS —particularly from Gamma (γ) to Beta (β)—there are regions of especial beauty and charm.

Note also the fine double cluster in PERSEUS, lying almost on a line between Eta (η) in that constellation and Epsilon (ε) in CASSIOPEIA. It is marked χ-*h* [309]. Just now, however, it is too low—except in far northern latitudes—for satisfactory observation. Among the wide double stars, the following may be divided by a field-glass, if the glass be steadily held: the Nu (ν) [162] in the head of DRACO; Epsilon (ε) [263], Delta (δ) [266], and Zeta (ζ) [265] in LYRA; Delta (δ) [101] in CEPHEUS; and Omicron (ο) [148] in CYGNUS. Near the foot of the Cross note also the little star marked *6* [426].

MIZAR is the name of the star marked Zeta (ζ) [401] at the bend of the Dipper's handle. Quite near, and involved in the same stellar system with the brighter star, is the small star marked *g*. Its name is ALCOR [402]. As will be seen under the reference number in the Observer's Catalogue [401], recently discovered facts have given new interest to these well-known stars.

II. WITH A TWO-INCH TELESCOPE the beginner should first examine the preceding objects. MIZAR, however, to which we have just referred, is rather high just now for convenient study. Toward the west—if the mists of the horizon have not clouded them—be sure to examine CASTOR [186] in GEMINI and Gamma (γ) [227] in LEO. Both are fine objects; the latter the more difficult of the two. The beginner need not feel discouraged if his first attempt to separate the components should not succeed. Near to Gamma (γ) is also a small "neighbor star" having only an optical connection with the binary system; see p. 13. The real double is a very close pair in either a two-inch or three-inch instrument.

But whatever the disappointments in connection with the preceding star there will be none with the Beta (β) [147] of CYGNUS, extremely easy and yet singularly fine. A little closer and yet also a delightfully satisfactory object is the Gamma (γ) [157] of DELPHINUS. Easy objects will also be found in the Xi (ξ) [103] and Beta (β) [102] of CEPHEUS; in the Beta (β) [262] of LYRA; in the Zeta (ζ) [54] and Iota (ι) [53] of CANCER; in the *19* of LYNX [256]; and in the Delta (δ) [190] and Zeta (ζ) [193] of GEMINI—if the last named stars be not too near their setting to be clearly seen.

III. WITH A THREE-INCH TELESCOPE the objects already specified may be seen to even better advantage than with the two-inch. All should be viewed with an eye-piece of low power (from 40 x to 60 x) except in the cases of the Gamma (γ) [227] in LEO and CASTOR [186] in GEMINI. In the latter case 60 x will sometimes prove sufficient, though 75 x is better. Powers between 60 and 110 will also be needed for some of the following: the Eta (η) [82] in CASSIOPEIA, one of the finest of binary systems; the Mu (μ) [153] of CYGNUS, just to the right, or east, of LACERTA; and *61* [150], Omicron (ο) [148], and *17* [152], also in CYGNUS; as well as Eta (η) [308] in PERSEUS; and Omicron (ο) [163], Iota (ι) [164], and Gamma (γ) [165] in DRACO. In GEMINI, if the stars are not too low in the sky, try Kappa (κ) [189], Epsilon [191], and Lambda (λ) [192]. The last is the unmarked star which forms a small triangle with Delta (δ) and Zeta (ζ), both of which we have already mentioned. On a line extending the handle of the Little Dipper note the small star marked *19 H* [49].

In trying to divide POLARIS, the Pole-Star [406], use an eye-piece affording a power of from 75 to 100 on a three-inch instrument. At the present hour, the beginner may look for the small blue companion upward and toward the left from the brighter component.

NIGHT-CHART TO THE SKY AS THE OBSERVER FACES SOUTH.
JULY 1, 8 P.M., JUNE 15, 9 P.M., JUNE 1, 10 P.M., MAY 15, 11 P.M., MAY 1, 12 P.M.
FOR KEY-MAP TO THIS CHART SEE OPPOSITE PAGE.
FOR THE SKY AS THE OBSERVER FACES NORTH, SEE PP. 50, 51.
For the sky at other Dates and Hours see Time Schedule, p. 35.

**The Constellations. For the Telescopic Objects See the Page Opposite.**

The numbers in brackets [ ] refer to corresponding numbered notes in Observer's Catalogue, p. 116.

As we face toward the south, the stars of SCORPIO, or SCORPIUS [350], lie before us—a little to the left. SCORPIO rises at about the time ORION sets, and dominates the sky of midsummer almost as strikingly as ORION [290] dominates the sky of winter.

We may recognize the constellation, even through the haze which so often lies near the horizon, by the fan-like figure of six bright stars. This is formed of two groups, of three each. Alpha (α) or ANTARES [351] with Tau (τ) and Sigma (σ) form one group, pointing directly to the other—Beta (β), Delta (δ), and Pi (π). These stars—always in the same fixed relation to each other—may often be seen when the rest of SCORPIO is practically blotted out by fog or mist. The whole figure is so like the scorpion of the tropics, with its extended claws at Gamma (γ) and Xi (ξ),—its tail at Epsilon (ε) and Mu (μ)—extending to its sting at Lambda (λ), that it is the most realistic of the constellation outlines.

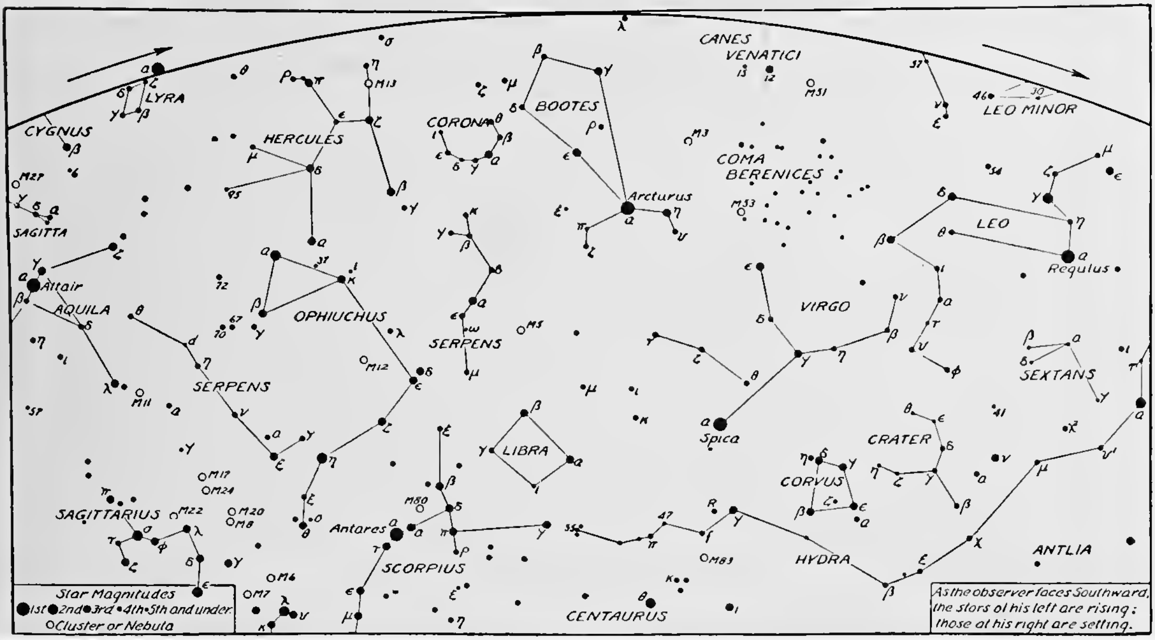
Directly to the west, or to the right, of SCORPIO shine the stars of LIBRA [245]—the BALANCES or SCALES. The fainter stars are not always visible, except when the night is very clear, and the group must often be recognized merely by Alpha (α) and Beta (β). To the right shines the white light of SPICA [416], the first-magnitude star of VIRGO [415]. Its recognition will be made even easier for us by the diagram on p. 26.

Below CORVUS, the RAVEN, or CROW [135], stretches the long line of HYDRA [210], the WATER-SNAKE, the whole length of which is shown on p. 49. Below the tail of HYDRA, very low in the sky near the center of our present map, are a few of the stars of CENTAURUS, the CENTAUR [90], one of the great constellations of the far southern skies. Theta (θ) is the only one of its brighter stars that can be seen from our latitudes.

Very high up shines ARCTURUS [41], the superb first-magnitude star of BOÖTES, the HERDSMAN. To the left is the pretty group called CORONA, or CORONA BOREALIS, the NORTHERN CROWN [130]. Farther still to eastward, or to the left, lie HERCULES [200], and LYRA, the LYRE [260]; and lower down lies AQUILA, the EAGLE [20], marked by the three stars in a row—Alpha (α) or ALTAIR [21], and Beta (β) and Gamma (γ). These are now about at position A as shown in the diagram on p. 28. Through the evening hours of the summer and autumn these three stars, which I have ventured to call "the shaft of Altair," form one of the finest landmarks of the sky. In studying BOÖTES and HERCULES the reader should turn to what has already been said on p. 42 and p. 46. Both are very high at the present hour, yet their figures are quite distinct. Below HERCULES and above SCORPIO there lies, however, one of the most difficult of the constellation outlines, OPHIUCHUS, or the SERPENT-BEARER [285], a difficult group.

Inability to distinguish this constellation need cause the beginner no discouragement. It has baffled many a veteran. Note the method for learning it suggested in the Observer's Catalogue [285], but if it is not clear at first, let it await your leisure—learning the other groups first. It should be studied in connection with SERPENS, the SERPENT [365], which lies on each side of it, the head to the observer's right, the tail to the left.

To the right of ARCTURUS, lies the scattered cluster of faint stars, COMA BERENICES, or BERENICE'S HAIR [120]; and still lower toward the west are the stars of LEO, the LION [225],—but with the familiar "sickle" turned downward more directly than here shown, with Beta (β) or DENEB'OLA higher up. REGULUS [226] makes with SPICA and ANTARES a fairly straight ine at almost equidistant spaces. The track of the planets, see p. 80, lies here through the constellations LEO, VIRGO, LIBRA, SCORPIUS, and SAGITTARIUS, the ARCHER [340]. The last is, as yet, hardly above the horizon, but the group is here outlined for observers who at a slightly later time may wish to trace its connection with SCORPIO; see paragraph 10, p. 31. Under the next map of the sky to the south it will receive fuller discussion; p. 56.




**KEY-MAP TO THE SKY AS THE OBSERVER FACES SOUTH.**
**JULY 1, 8 P.M., JUNE 15, 9 P.M., JUNE 1, 10 P.M., MAY 15, 11 P.M., MAY 1, 12 P.M.**
FOR NIGHT-CHART TO THIS MAP SEE OPPOSITE PAGE.
FOR THE SKY AS THE OBSERVER FACES NORTH, SEE PP. 50, 51.
For the sky at other Dates and Hours see Time Schedule, p. 35.

**The Telescopic Objects. For the Constellations See the Page Opposite.**

The numbers in brackets [ ] refer to corresponding numbered notes in Observer's Catalogue, p. 116.

I. WITH OPERA-GLASS OR FIELD-GLASS first note the interesting regions of SCORPIO, following the Scorpion's tail from his heart at Alpha (α) or ANTARES [351] to Tau (τ), and through Epsilon (ε) and Nu (ν), round to the end at Lambda (λ). This is one of the rich sections of the Milky Way.

The little star Mu (μ) [359] in SCORPIO is an easy and pretty double, though there is probably no real connection between the components; see p. 13. A field-glass will also indicate the delicate glimmer of the clusters marked M 80 [355], M 6 [356], and M 7 [357], provided the night be clear and the horizon unburdened by mist or fog. The same may be said of the clusters in SAGITTARIUS, the ARCHER [340], as soon as the fields of this constellation rise—a little later—into better position for observation. The easiest of these are M 8 [341] and M 24 [345].

Among the double stars that may be divided by a field-glass, steadily held, are the Alpha (α) [246] of LIBRA, the Tau (τ) [228] of LEO, and the Nu (ν) [353] of SCORPIO. The last is the small star, unmarked, just to the left, or east, of Beta (β). With opera-glass or field-glass do not fail to sweep through the fine scattered cluster called COMA BERENICES, or BERENICE'S HAIR [120], lying just above a line connecting ARCTURUS and the Beta (β) of LEO. Trace out, also, the pretty figure of CORONA, the CROWN [130]. There is a cluster of 8th magnitude stars near to Beta (β) in OPHIUCHUS [288].

II. WITH A TWO-INCH TELESCOPE, examine, first, the objects already noted; especially the Alpha (α) [246] of LIBRA, and the double stars of SCORPIO, Beta (β) [352], Nu (ν) [353], and Mu (μ) [359]. These are all extremely easy and yet none the less interesting. In the case of Nu (ν) [353], it is worth while to remember that each of the two components is itself a double star when viewed in a very large telescope. In addition to the above try Sigma (σ) [358]; and Xi (ξ) [354], above Beta (β) in the same constellation; Delta (δ) [136] in CORVUS; the Gamma (γ) [417] in VIRGO; and the Gamma (γ) [227] in LEO. For the last, see also the text under the northward map for this same hour; p. 51.

Turning eastward, or to the left, try the stars marked *67* [286] and *70* [287] in OPHIUCHUS—the former is the easier; and Theta (θ) [368] in SERPENS. The last named star is not easily found when so low in the sky, but we may note that it lies to our left from OPHIUCHUS, just to one side of a line connecting the Zeta (ζ) and Lambda (λ) of AQUILA. You will see from the Night-Chart that each of these guide stars is one of an obvious pair. Another method for finding our object is noted in the Observer's Catalogue. Space has been given to such directions because the Theta (θ) [368] of SERPENS is of unusual charm and beauty.

III. WITH A THREE-INCH TELESCOPE and with instruments larger than a three-inch the objects already named should first have careful examination. To these may be added the Alpha (α) [416], Theta (θ) [418], and Tau (τ) [419] of VIRGO; the Iota (ι) [248] of LIBRA; the Xi (ξ) [251] of LUPUS, just below SCORPIO; the Alpha (α) [201] of HERCULES, a superb object; and—in the same constellation—the stars marked Mu (μ) [203], *95* [205], Gamma (γ) [208], and Rho (ρ) [204]. Try also the Zeta (ζ) [131] of CORONA; and the Mu (μ) [47], Delta (δ) [43], Xi (ξ) [43 b], Pi (π) [44], and Epsilon (ε) [42] of BOÖTES. The last named star is a fine object but difficult except in a larger telescope. A number of the stars just mentioned are so easy as to be properly objects for a two-inch, but they are now so high that an instrument of larger aperture, with a low-power eye-piece, will find them more readily and permit a more satisfactory view of them. View also with such an eye-piece the clusters and nebulæ M 17 [344], M 20 [342], and M 22 [343] in SAGITTARIUS, as well as those already mentioned. The cluster M 5 [371] in SERPENS forms an equilateral triangle with Mu (μ) and Epsilon (ε) in that constellation; or it may be found by a line from Iota (ι) to Beta (β) in LIBRA continued onward a like distance.

NIGHT-CHART TO THE SKY AS THE OBSERVER FACES NORTH.
SEPT. 1, 8 P.M., AUG. 15, 9 P.M., AUG. 1, 10 P.M., JULY 15, 11 P.M., JULY 1, 12 P.M.

FOR KEY-MAP TO THIS CHART SEE OPPOSITE PAGE.
FOR THE SKY AS THE OBSERVER FACES SOUTH, SEE PP. 56, 57.
For the sky at other Dates and Hours see Time Schedule, p. 35.

**The Constellations. For the Telescopic Objects See the Page Opposite.**

The numbers in brackets [ ] refer to corresponding numbered notes in Observer's Catalogue, p. 116.

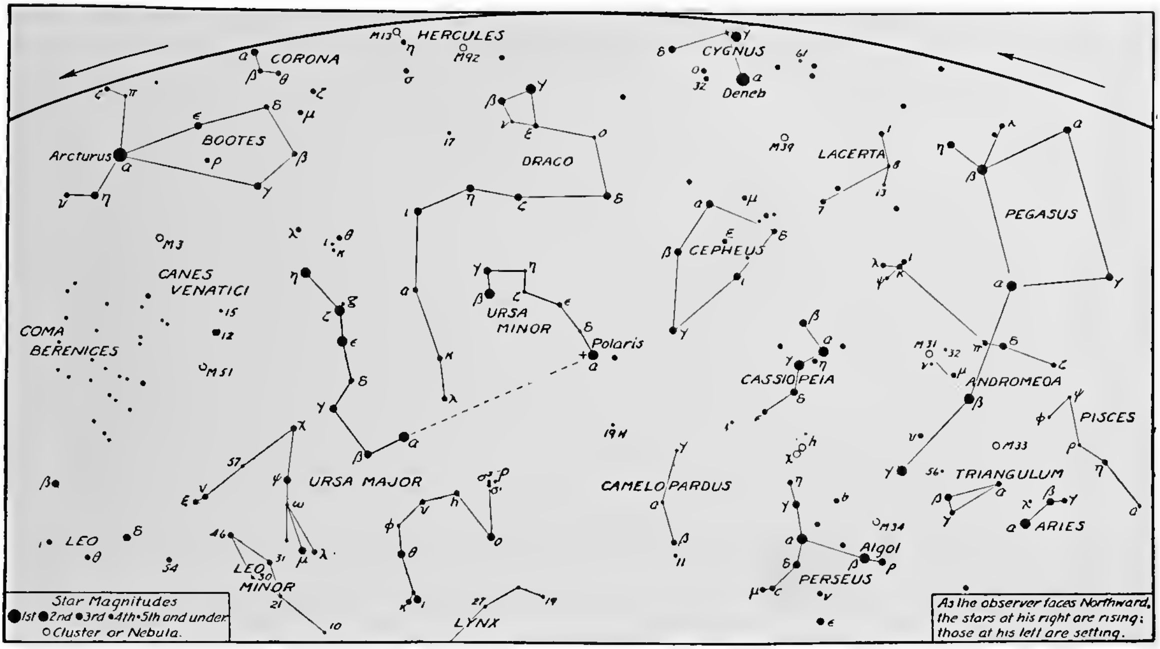
As we face toward the north, we find that the Great Dipper, in its revolution round the Pole, is at our left, rather low, with the bowl of the Dipper turned eastward. If we turn to the diagram on p. 23, we may see that the Dipper is proceeding now from position D to position A, its stars Beta (β) and Alpha (α) still pointing, however, to POLARIS, the Pole-Star [406].

URSA MAJOR, or the GREAT BEAR [400], of which the Great Dipper is the only conspicuous part, is supposed to have his nose at Omicron (ο), his ears at Sigma (σ) and Rho (ρ), his forefeet at Kappa (κ) and Iota (ι), and his hind feet at Mu (μ) and at Xi (ξ). There is a long tail—quite contrary to what we know of bears—and this tail is the "handle" of our Dipper,—the stars from Delta (δ) to Eta (η). The Pole-Star is, of course, the brightest object in URSA MINOR, the LITTLE BEAR [405], the chief stars of which make the outline of what we call the Little Dipper.

A dotted line in the Key Map will be seen to run from the "Pointers" Alpha (α) and Beta (β) in the Great Dipper to POLARIS. If we continue this line clear across the northern sky, it will pass through the roof of the dim house-shaped figure called CEPHEUS [100], dividing it from the W-shaped figure of CASSIOPEIA [80], just below, and will at length "find" the star Beta (β) in the great square of PEGASUS, the WINGÈD HORSE [301]. This square is formed by four bright stars, the Beta (β), Alpha (α), and Gamma (γ) of PEGASUS, and the Alpha (α) of ANDROMEDA [1]. Here, however, let us note that so large a figure, coming at the very edge of the map, suffers an unusual amount of distortion; see pp. 4 and 6. Keep in mind, therefore, the fact that the upward lines which form in the Key Map the longer sides of the square, bear toward the right rather than toward the left, and are thus at present more nearly parallel to the horizon than they appear to be in the map. Not that they are now so level with the horizon as drawn on p. 57. The truth of the case —which could not be well shown except on a globe—lies between the two representations; and the observer, by one glance at the actual sky, will be able to make the needed correction. We will speak of the figure of PEGASUS under our southward map, p. 56, where also the Northern Cross, in CYGNUS, the SWAN [145] is fully drawn.

From PEGASUS the fine constellation of ANDROMEDA, the story of which will be found in the Observer's Catalogue [1], stretches away, in an almost straight line, toward PERSEUS [305], the Alpha (α) of PERSEUS seeming to terminate a fine series of almost equi-distant second-magnitude stars,—the others being the Beta (β) of PEGASUS, and the Alpha (α), Beta (β), and Gamma (γ) of ANDROMEDA. PERSEUS, moving to the rescue, bears an uplifted sword—the handle being at the cluster marked $\chi$-$h$ [309]—and carries also the terrible head of Medusa, represented by Beta (β) or Algol [307]. To the right of PERSEUS and eastward from ANDROMEDA, the stars of TRIANGULUM, the TRIANGLE [395], ARIES, the RAM [30], and PISCES, the FISHES [320], are just rising, but the last named is too low down as yet for clear observation.

Looking again directly north, we see that the tail of DRACO, the DRAGON [160], trails downward between the Great Dipper and the Little Dipper, the Dragon's head being high above us at the stars Gamma (γ) and Beta (β). The handle of the Great Dipper, if we continue its curve, points us to the great star ARCTURUS [41] in BOÖTES, the HERDSMAN [40]. The kite-shaped figure points more directly downward, however, than shown above,—ARCTURUS being much lower in the west than Beta (β). Just to the left from the Dipper is the small constellation called CANES VENATICI, the HUNTING DOGS [60]. They are supposed to belong to the HERDSMAN and to be aiding him as he chases the GREAT BEAR round the Pole. They form, of course, no outline of dogs or of anything else. Still further to our left, or westward, lies the scattered cluster of little stars called COMA BERENICES, or BERENICE'S HAIR [120].




**KEY-MAP TO THE SKY AS THE OBSERVER FACES NORTH.**
**SEPT. 1, 8 P.M., AUG. 15, 9 P.M., AUG. 1, 10 P.M., JULY 15, 11 P.M., JULY 1, 12 P.M.**

FOR NIGHT-CHART TO THIS MAP SEE OPPOSITE PAGE.
FOR THE SKY AS THE OBSERVER FACES SOUTH, SEE PP. 56, 57.
For the sky at other Dates and Hours see Time Schedule, p. 35.

**The Telescopic Objects. For the Constellations See the Page Opposite.**

The numbers in brackets [ ] refer to corresponding numbered notes in Observer's Catalogue, p. 116.

I. WITH OPERA-GLASS AND FIELD-GLASS, first observe the varied cluster of small stars called COMA BERENICES, or BERENICE'S HAIR [120]. It may be found by prolonging an imaginary line from POLARIS to Epsilon (ε) in the handle of the Great Dipper.

At the bend in the Dipper's handle note the little star marked *g*. It is called ALCOR [402], and the bright star quite near it is called MIZAR [401]. Note also the group of little stars just above, at Theta (θ). These belong to BOÖTES. There is another little group marking the Bear's ear at Sigma (σ) in URSA MAJOR. The Milky Way is now almost perpendicular to the horizon, running through PERSEUS, CASSIOPEIA, and the corner of CEPHEUS, to CYGNUS. See p. 19.

In PERSEUS there is a star-field of exceptional beauty near the star Alpha (α) [306]. There are other fine fields in CASSIOPEIA; and the famous double cluster which marks the sword handle of PERSEUS lies between these two constellations, almost on a line between Delta (δ) in the former group and Eta (η) in the latter. It is marked χ-*h* [309].

Among the double stars that may be divided by a field-glass or opera-glass, held steadily, are Nu (ν) [162] in the head of DRACO; the star marked *15* [62] in CANES VENATICI; Delta (δ) [101] in CEPHEUS; and the little star marked *56* [5] in ANDROMEDA. The last is in line with the Gamma (γ) and Beta (β) of TRIANGULUM.

II. WITH A TWO-INCH TELESCOPE, first examine the objects already mentioned, noting especially the star marked Zeta (ζ) [401], at the bend in the Dipper's handle, for—as will be seen from the Observer's Catalogue—it is an object of especial interest and importance.

In the group called CANES VENATICI, note not only *15*, to which we have already referred, but the star marked *12* [61]; and, almost on a line with these stars, the place of the nebula marked M 51 [63]. This is beyond the scope of small instruments. It is here indicated merely because its singular structure—see p. 11—has made its location a matter of general interest. The star *12* [61] is a beautiful and easy double; it is in line with POLARIS and the star Epsilon (ε) in the handle of the Great Dipper. A glimpse may now be had of the great nebula in ANDROMEDA, M 31 [2], forming a triangle with the little stars Nu (ν) and *32*. Note also the cluster M 34 [311] in PERSEUS, M 33 [396], above the Alpha (α) of TRIANGULUM, and M 3 [64], almost on a line between ARCTURUS and the star *12* of CANES VENATICI. Other double stars for a two-inch instrument are Mu (μ) [47], Delta (δ) [43], and Pi (π) [44] in BOÖTES; and Kappa (κ) [45] and Iota (ι) [46] in the same constellation. The two just mentioned are almost in URSA MAJOR, being above, and to the right of, the tip of the Dipper's handle. Examine also the Xi (ξ) [103] and Beta (β) [102] of CEPHEUS; the Lambda (λ) [31] and Gamma (γ) [32] of ARIES; and the Gamma (γ) [3] of ANDROMEDA. The last is one of the most charming of all the double stars.

III. WITH A THREE-INCH TELESCOPE, the preceding objects may be seen to still better advantage: all should be examined, for they are not any less appropriate for a three-inch. In addition to these, try the double stars Eta (η) [308] and Zeta (ζ) [310] in PERSEUS; and Iota (ι) [83] and Eta (η) [82] in CASSIOPEIA,—the latter a beautiful and interesting binary system.

An imaginary line prolonging the handle of the Little Dipper will find the little star marked *19 H* [49], an easy double. Use a low power eye-piece. Upon the other hand, the star Epsilon (ε) [42] in BOÖTES will demand an eye-piece of high power, and the beginner may need a telescope of larger size, three and one-quarter to three and three-quarter inches of aperture, for its division. The contrast in the colors of the components is very fine. POLARIS, the Pole-Star [406], can be divided by a three-inch instrument, with an eye-piece having a power of 75 to 100. The small blue companion is always worth seeing and pondering. At this hour it is to the left, but downward, from the brighter component.

NIGHT-CHART TO THE SKY AS THE OBSERVER FACES SOUTH.
SEPT. 1, 8 P.M., AUG. 15, 9 P.M., AUG. 1, 10 P.M., JULY 15, 11 P.M., JULY 1, 12 P.M.

FOR KEY-MAP TO THIS CHART SEE OPPOSITE PAGE.
FOR THE SKY AS THE OBSERVER FACES NORTH, SEE PP. 54, 55.
For the sky at other Dates and Hours see Time Schedule, p. 35.

**The Constellations. For the Telescopic Objects See the Page Opposite.**

The numbers in brackets [ ] refer to corresponding numbered notes in Observer's Catalogue, p. 116.

Facing south, we now find the stars of SAGITTARIUS, the ARCHER [340], directly before us, low toward the horizon. The ARCHER was supposed to be a Centaur, but nothing of this creature—half-horse and half-man—appears in the outline of the stars.

The bow, however, is clearly pictured by the stars Lambda (λ), Delta (δ) and Epsilon (ε). The arrow's tip is at Gamma (γ) and the hand is at Zeta (ζ), drawing back the arrow for its flight toward SCORPIUS. The head of the ARCHER is at Pi (π). The stars Lambda (λ), Phi (φ), Sigma (σ), Tau (τ), and Zeta (ζ) form, if taken by themselves, a figure like a dipper up-side-down; and this has long been recognized as the "Milk Dipper."

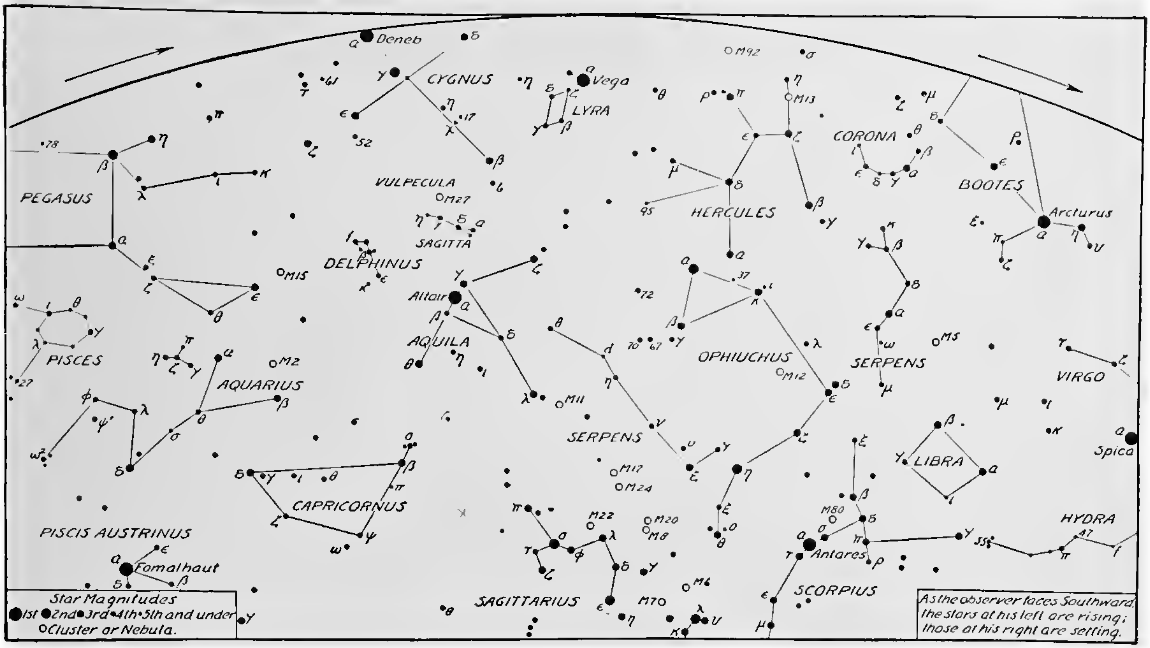
Eastward or to the left, shines ALTAIR [21], the beautiful first-magnitude star of AQUILA, the EAGLE [20]. It can always be identified on a clear night by the two almost equidistant stars Gamma (γ) and Beta (β). They serve also to point us, in a general way, toward LYRA, the LYRE [260], with its bright star VEGA [261]; and—in the other direction—toward the faint stars of CAPRICORNUS, the SEA GOAT [75]. See also p. 28.

To the east of LYRA shines CYGNUS, the SWAN [145], forming also the Northern Cross; and to westward from LYRA is the figure of HERCULES [200], but these constellations are now so inconveniently placed for observation that we only refer, here, to pp. 38 and 46, and to what is said concerning them under their reference numbers in the Observer's Catalogue. To the latter source we may also refer for the figure of OPHIUCHUS, the SERPENT-BEARER [285], and SERPENS, the SERPENT [365], both of which are below HERCULES and somewhat lower in the sky.

Returning to AQUILA, we may note that the stars of the constellation really form no likeness of an eagle, and we are able to draw the outline shown in the Key-Map, only by making a somewhat arbitrary selection of the stars. The same may be said of AQUARIUS, the WATER-BEARER [15], except that here the effort to find an image appropriate to the name must be even more futile. We must assume that the man lies almost on his back, with shoulders at Alpha (α) and Beta (β), waist at Delta (δ) and knees at Lambda (λ) and Phi (φ). One object, at least, is clearly and prettily marked,—the mouth of the Water Jar, formed by the little Y-shaped figure at Pi (π), Eta (η), and Gamma (γ). In the lines of faint stars running downward through Phi (φ) and Omega (ω), and onward, some have seen the trickling of a jewelled stream into the mouth of the SOUTHERN FISH, PISCIS AUSTRINUS [330];—for the mouth of the Fish is marked by FOMALHAUT [331], a fine first-magnitude star. At this hour, precisely, FOMALHAUT is not yet quite above the horizon in our northern latitudes.

Northward from AQUARIUS, the great square of PEGASUS, the WINGED HORSE [301], is now apparent. As PEGASUS is so great in size and as it is divided between the south and north, the text and maps here should be supplemented by those on pp. 54, 55. The shoulders and body of the horse are represented by the "square"; the head is toward the south, at the stars Zeta (ζ), Theta (θ), and Epsilon (ε); and the forefeet are at Eta (η) and Kappa (κ). The huge animal has, therefore, his back toward the horizon, his feet in air. The "square" is formed only by including the Alpha (α) of ANDROMEDA, as explained under the preceding Night Chart; and the explanation of the distortion there, is applicable here.

Turning again to the south, we see that the stars of SCORPIUS, or SCORPIO [350], are sinking toward the west, but the fan-shaped figure made by the six bright stars—ANTARES [351], Tau (τ) and Sigma (σ) in one group; and Beta (β) Delta (δ), Pi (π) in the other—is still distinct. Westward from SCORPIO is LIBRA [245], the BALANCES or SCALES; and still farther westward and northward, the superb ARCTURUS [41] leads the HERDSMAN, BOÖTES, beyond our ken. Between the latter constellation and HERCULES [200] shines the charming figure of CORONA BOREALIS [130], or the NORTHERN CROWN.




KEY-MAP TO THE SKY AS THE OBSERVER FACES SOUTH.

SEPT. 1, 8 P.M., AUG. 15, 9 P.M., AUG. 1, 10 P.M., JULY 15, 11 P.M., JULY 1, 12 P.M.

FOR NIGHT-CHART TO THIS MAP SEE OPPOSITE PAGE.
FOR THE SKY AS THE OBSERVER FACES NORTH, SEE PP. 54, 55.
For the sky at other Dates and Hours see Time Schedule, p. 35.

**The Telescopic Objects. For the Constellations See the Page Opposite.**

The numbers in brackets [ ] refer to corresponding numbered notes in Observer's Catalogue, p. 116.

I. With opera-glass and field-glass sweep, first, through the course of the Milky Way. It here runs almost through the centre of the map,—from Cygnus, through Sagitta, Aquila, and Sagittarius,—swerving slightly westward as it descends, and including the tail of Scorpio.

In this region we shall be able on a clear, moonless night to catch a glimpse of the clusters marked M 8 [341], M 7 [357], M 6 [356], and M 22 [343]; and possibly of M 80 [355] also—just on a line, in Scorpio, between Alpha (α) and Beta (β). Among larger groups the stars of Corona [130] form a beautiful spectacle. A field-glass or, in some cases, an opera-glass will divide the following double stars: those marked Alpha (α) [76] and Beta (β) [77] in Capricornus; the star marked *6* [426] near the foot of the Cross in Cygnus; Epsilon (ε) [263], Delta (δ) [266], and Zeta (ζ) [265] in Lyra,—now very high up; Mu (μ) [359] in Scorpio, and Alpha (α) [246] in Libra, now low in the southwest.

II. For a two-inch telescope, the preceding objects are of course available; and all are worthy of the beginner's interest and study. Try also the double stars marked Sigma (σ) [358], Beta (β) [352], and Nu (ν) [353] in Scorpio,—the last is the unmarked star to the left from Beta (β). Examine Xi (ξ) [354] also, just above Beta (β). These will be found easy but very fine. Try, too, the stars *67* [286] and *70* [287] in Ophiuchus; and Theta (θ) [368] in Serpens. The latter is the easiest of the three, and one of the loveliest of its class.

We have already spoken frequently of the star in Cygnus, marked *61* [150]; and of Beta (β) [147],—one of the finest objects for a small instrument. Try also the doubles in Lyra, marked Beta (β) [262] and Eta (η) [264]. Interesting double stars are also to be found in the Alpha (α) [201] and Delta (δ) [202] of Hercules—the former is especially beautiful; in the Zeta (ζ) [131] of Corona; and in the Pi (π) [44] and Delta (δ) [43] of the constellation Boötes.

Returning to the region of Aquila, the Gamma (γ) [157] of Delphinus, not far from Altair, should not be forgotten. Another fine double, though a little more difficult than the last, is the Zeta (ζ) [17] of Aquarius, the star at the centre of the little Y-shaped figure that marks the mouth of the water-jar. Try also the star Psi (ψ') [18] in the same constellation. As Piscis Austrinus, the Southern Fish, rises a little higher in its course, the star Beta (β) [332] will be found an easy double.

III. With a three-inch telescope, the beginner will do well to examine the objects already mentioned for the field-glass and the two-inch. With an eye-piece of low power, we may note the following star clusters and nebulae—if the air be clear and the sky be free from moonlight. To those already listed, add M 22 [343] and M 17 [344] in Sagittarius; M 12 [289] in Ophiuchus; M 13 [206] in Hercules, though this is now too high for convenient examination; M 2 [16] in Aquarius; M 11 [23] in Aquila, near to Lambda (λ); M 27 [427] in Vulpecula, forming an acute triangle with the Eta (η) and Gamma (γ) of Sagitta; M 15 [303], in line with the Theta (θ) and Epsilon (ε) of Pegasus; and—far westward —M 5 [371] in Serpens, called a "variable" cluster because in it have been detected more than a hundred variable stars. There is also a pretty cluster near Beta (β) in Ophiuchus, see [288].

To the double stars already listed, add the Gamma (γ) [333] of Piscis Austrinus; the Pi (π) [79] of Capricornus; the Epsilon (ε) [302] of Pegasus; the Alpha (α) [156] of Delphinus; *17* [152] in Cygnus; Mu (μ) [203], *95* [205], and Rho (ρ) [204] and Gamma (γ) [208] in Hercules; Iota (ι) [248] in Libra; and Epsilon (ε) [42] in Boötes. The last may require a telescope of slightly larger aperture. Such may also prove necessary with Vega in Lyra [261] and Antares [351] in Scorpio. The track of the planets, see p. 80, passes here through Virgo, Libra, Scorpius, Sagittarius, Capricornus, Aquarius, and Pisces.

NIGHT-CHART TO THE SKY AS THE OBSERVER FACES NORTH.
NOV. 1, 8 P.M., OCT. 15, 9 P.M., OCT. 1, 10 P.M., SEPT. 15, 11 P.M., SEPT. 1, 12 P.M.

FOR KEY-MAP TO THIS CHART SEE OPPOSITE PAGE.
FOR THE SKY AS THE OBSERVER FACES SOUTH, SEE PP. 60, 61.
For the sky at other Dates and Hours see Time Schedule, p. 35.

**The Constellations. For the Telescopic Objects See the Page Opposite.**

The numbers in brackets [ ] refer to corresponding numbered notes in Observer's Catalogue, p. 116.

The Great Dipper is now directly before us, low in the sky, as we face due north. From the diagram on p. 23, we may see that, in its revolution round the Pole of the heavens, it has passed from position A to position B; from B to C; from C to D; and is now almost at position A again. These seven stars are but the brighter part of the constellation URSA MAJOR, the GREAT BEAR [400].

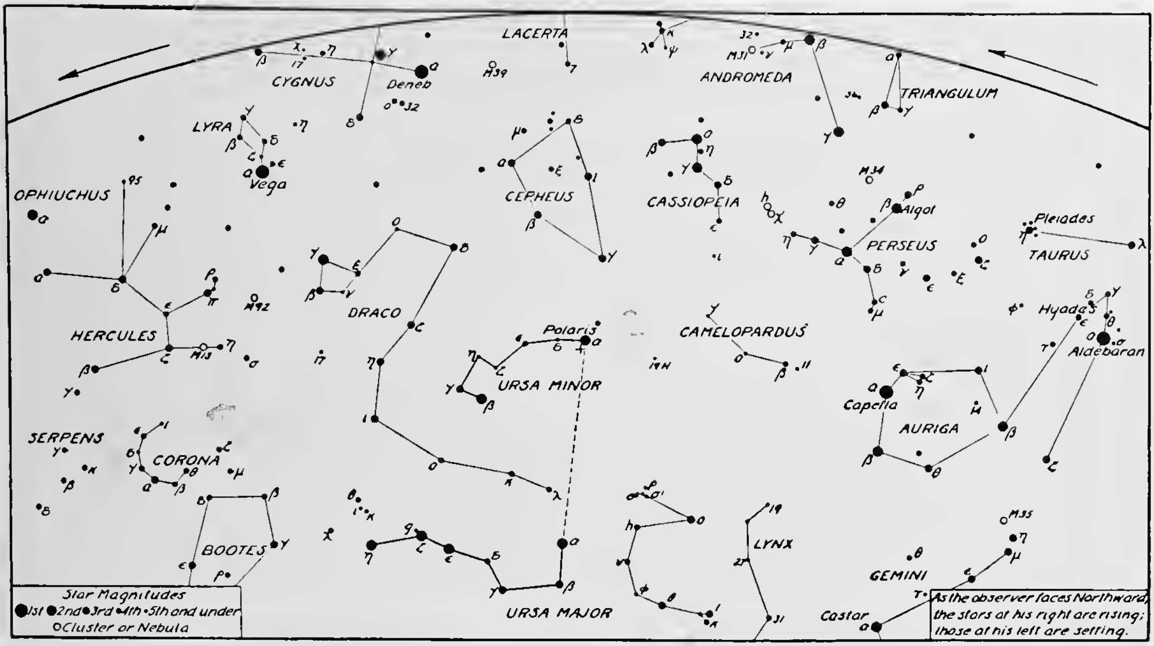
Two of these stars, Alpha (α) and Beta (β), point us always in the general direction of POLARIS, the Pole-star, which is the brightest star in the Little Dipper. Its outline is not always clear because some of its stars are quite faint, but it forms the chief part of URSA MINOR, the LITTLE BEAR [405].

Looking carefully at the Little Dipper, we may see that its handle, with POLARIS at the tip, is pointing toward the east at our right hand. In a general way it points us toward two bright stars,—stars of the first magnitude. The whiter of these stars is CAPELLA [36], the finest object in the constellation AURIGA, the CHARIOTEER [35]. The reddish star is ALDEB'ARAN [381] in the constellation TAURUS, the BULL [380]. Of the constellations called LYNX [255] and CAMELOPARDUS the GIRAFFE [48], little need be said, as they are too faint and unimportant for discussion here.

We shall see near CAPELLA (the name means literally She-Goat) three little stars forming an acute triangle. These, Epsilon (ε), Zeta (ζ), and Eta (η), have for uncounted centuries been known as "The Kids." AURIGA, the CHARIOTEER, is supposed to be bearing the Goat and her kids in his arms. TAURUS, the BULL, with his red eye at ALDEB'ARAN, and his two horns stretching away to Zeta (ζ) and Beta (β), shares the latter star with AURIGA; though, strictly, it belongs to TAURUS. In this great constellation lie the two fine star-clusters, the PLEIADES [382] and the HYADES [383]. The PLEIADES represent perhaps the most widely interesting of all the minor star groups: see pp. 17, 19. In looking at the HYADES, we should remember that the apex of the triangular figure ending at Gamma (γ) is not tipped upward so much as in the diagram. We may here correct the distortion at the map's edge by noting that the line, for example, from Alpha (α) to Gamma (γ) is more nearly parallel to the horizon.

Above AURIGA shines PERSEUS [305], and to the left we may see the W-shaped figure of CASSIOPEIA [80], sometimes called the LADY OF THE CHAIR; and the house-shaped figure of CEPHEUS [100]. Of these groups we have spoken more fully on pp. 46 and 50. We may find the head of DRACO, the DRAGON [160], by noting that it is practically in line with Beta (β) in URSA MINOR, and the bright star VEGA in LYRA. Gamma (γ), the brightest of DRACO's stars, is also in line with the cross-beam of the Northern Cross in CYGNUS [145].

LYRA, or the LYRE [260], is a small constellation, but one of the most interesting. It may be identified by the brilliancy of VEGA [261], its beautiful first-magnitude star, and by the figure formed by the smaller stars, Beta (β), Delta (δ), Gamma (γ), and Zeta (ζ). Below LYRA are the stars of HERCULES [200]. Here the beginner should first trace the outline of the "hopper" or the "key-stone" formed by Pi (π), Epsilon (ε), Zeta (ζ), and Eta (η). To these should be added the line from Epsilon (ε) to Delta (δ) and Alpha (α), and the line Beta (β) to Zeta (ζ). The lines to Mu (μ) and *95* are merely to aid the user of a telescope, and are not important. Below HERCULES is the pretty figure of CORONA, or CORONA BOREALIS, the NORTHERN CROWN [130]. Very low at the northwest, the few remaining stars of BOÖTES, the HERDSMAN [40], are setting, and at the northeast, at our right, the stars of GEMINI, the TWINS [185], are just rising; see the maps on pp. 38 and 40, as these come next, in the order of our series. CASTOR [186] rises first, soon to be followed by the more brilliant POLLUX [187]. The whole constellation is of especial importance; see Observer's Catalogue, under reference numbers just given.




KEY-MAP TO THE SKY AS THE OBSERVER FACES NORTH.

NOV. 1, 8 P.M., OCT. 15, 9 P.M., OCT. 1, 10 P.M., SEPT. 15, 11 P.M., SEPT. 1, 12 P.M.

FOR NIGHT-CHART TO THIS MAP SEE OPPOSITE PAGE.

FOR THE SKY AS THE OBSERVER FACES SOUTH, SEE PP. 60, 61.

For the sky at other Dates and Hours see Time Schedule, p. 35.

**The Telescopic Objects. For the Constellations See the Page Opposite.**

The numbers in brackets [ ] refer to corresponding numbered notes in Observer's Catalogue, p. 116.

I. For opera-glass or field-glass, there are now before us some interesting regions of the Milky Way, which runs, here, through Cygnus, Cepheus—near Delta (δ); Cassiopeia; Perseus—note especially the field about Alpha (α) [306]; and Auriga—flowing by Epsilon (ε) and to the right of Theta (θ); and on through the feet of Gemini. Note here the fine cluster marked M 35 [188], forming an obtuse triangle with the stars Mu (μ) and Eta (η).

The most beautiful and impressive of all spectacles for such a glass is, of course, the Pleiades [382]. Note also the Hyades [383]. In this group it is well to observe especially the little pairs marked Theta (θ) [386] and Sigma (σ) [389]. There is a slight distortion in the map here which can be easily corrected by the suggestions given in col. 2, p. 58.

Turning westward, or to the left, we may detect, perhaps, the double cluster marked χ-*h* [309] between Perseus and Cassiopeia. On p. 4, and under its reference number in the Observer's Catalogue, we have spoken of it more fully.

Among the important double stars, Zeta (ζ) [401] and *g* at the bend in the handle of the Great Dipper may usually be divided from each other by the unaided eye. These are named Mizar and Alcor; see p. 39. Zeta (ζ) itself will of course require a telescope for its division. The preceding stars and some of the following may be divided by an opera-glass, as well as by a field-glass:—the Nu (ν) [162] in the head of Draco; Epsilon (ε) [263], Delta (δ) [266], and Zeta (ζ) [265] in Lyra; Delta (δ) [101] in Cepheus; and Omicron (ο) [148] in Cygnus.

II. With a two-inch telescope, the objects already listed may be examined to even greater advantage. Each is worth while. To the double stars may be added the Tau (τ) [387], Phi (φ) [391], and Eta (η) [384] of Taurus; the star marked *14* in Auriga [38]; Beta (β) [102] and Xi (ξ) [103] in Cepheus; Delta (δ) [202] and Alpha (α) [201] in Hercules; and Delta (δ) [43], Mu (μ) [47], Kappa (κ) [45], and Iota (ι) [46] in Boötes. The last two are now just above Eta (η) of Ursa Major, at the end of the Dipper's handle. At the bend of the handle is Zeta (ζ) [401], or Mizar, probably the most interesting and important of all the double stars within range of a two-inch telescope. The star marked Beta (β) [147] at the foot of the Cross in Cygnus is now very high up, but it is a beautiful object, and well worth the effort if the beginner can get it into the field of his instrument. Even finer is the Gamma (γ) [3] of Andromeda,—which forms a right angled triangle with the Alpha (α) and Beta (β) of Perseus.

III. With a three-inch telescope the preceding objects are available. The Alpha (α) [201] of Hercules; the Beta (β) [147] of Cygnus; the Gamma (γ) [3] of Andromeda; and the Zeta (ζ) [401] of Ursa Major are of especial interest and beauty. The star-clusters, including the Pleiades [382] and the Hyades [383] in Taurus, and M 35 [188] in Gemini are fine under low powers.

To the double stars listed for the field-glass and the two-inch telescope, the following may be added to the list for a three-inch: The Zeta (ζ) [131] of Corona; the stars marked *95* [205], Mu (μ) [203], Rho (ρ) [204], and Gamma (γ) [208] of Hercules; the Beta (β) [262] and Eta (η) [264] of Lyra; the star marked *17* [152] in Cygnus; Delta (δ) [166], Omicron (ο) [163], Iota (ι) [164], and Gamma (γ) [165] in Draco; the star marked *19 H* [49] to the right of Polaris; Eta (η) [308] and—more difficult—Zeta (ζ) [310] in Perseus; and Iota (ι) [83] and Eta (η) [82] in Cassiopeia. The last two stars are not easy objects, but the latter represents an interesting binary system, and the contrast in the colors of the components is singularly fine. Polaris [406], or the Pole-Star, is always of interest; and the ninth-magnitude companion will be found at this hour almost directly below the brighter component. Try a power of 75; an even lower power is often sufficient.

NIGHT-CHART TO THE SKY AS THE OBSERVER FACES SOUTH.
NOV. 1, 8 P.M., OCT. 15, 9 P.M., OCT. 1, 10 P.M., SEPT. 15, 11 P.M., SEPT. 1, 12 P.M.
FOR KEY-MAP TO THIS CHART SEE OPPOSITE PAGE.
FOR THE SKY AS THE OBSERVER FACES NORTH, SEE PP. 58, 59.
For the sky at other Dates and Hours see Time Schedule, p. 35.

**The Constellations. For the Telescopic Objects See the Page Opposite.**

The numbers in brackets [ ] refer to corresponding numbered notes in Observer's Catalogue, p. 116.

At this hour, as we face southward, the bright first-magnitude star directly before us, low in the sky, is called FOMALHAUT [331]. This is the brightest object in the SOUTHERN FISH, or PISCIS AUSTRINUS [330] as the constellation is called in Latin. Above it is AQUARIUS [15], the WATER-BEARER, looking even less like the figure of a man than the stars below look like a fish.

The mouth of the water-jar in AQUARIUS is marked by the little Y-shaped figure at Pi ($\pi$), Eta ($\eta$), and Gamma ($\gamma$). This is the group by which the constellation is usually identified. AQUARIUS is represented with head near the nebula marked M 2; shoulders at Alpha ($\alpha$) and Beta ($\beta$); waist at Delta ($\delta$), knees at Lambda ($\lambda$) and Phi ($\phi$), and feet about at Omega ($\omega$). The present position of the body is thus almost parallel to the horizon.

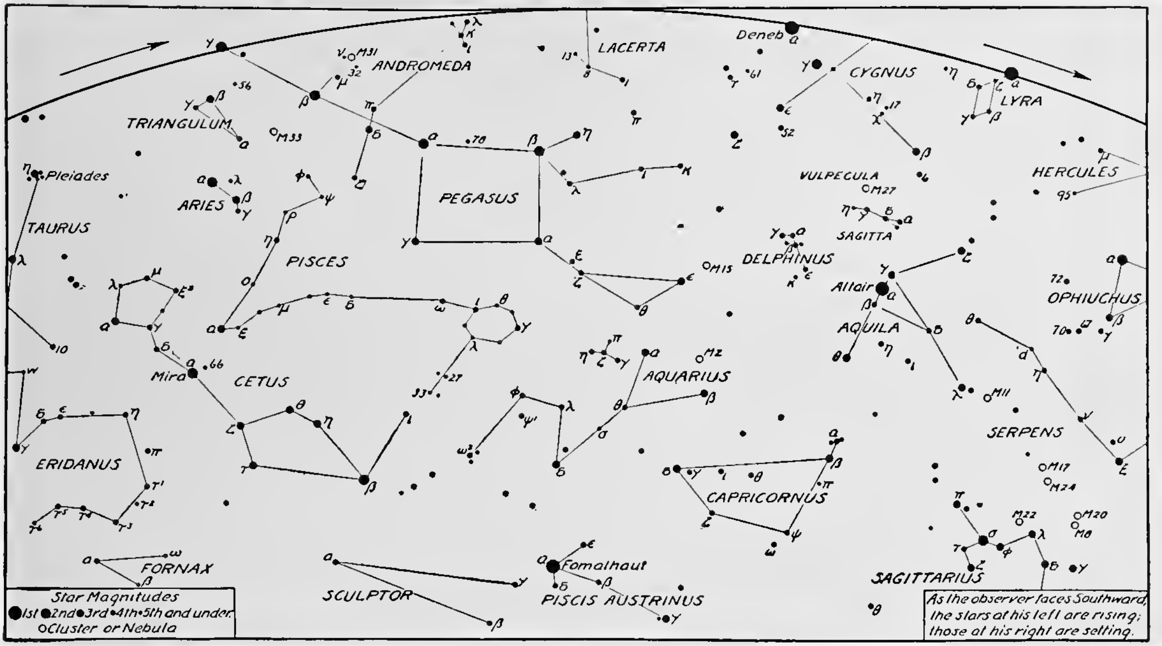
Above AQUARIUS is PEGASUS, the WINGED HORSE [301], the head represented by the obtuse triangle, Zeta ($\zeta$), Theta ($\theta$), Epsilon ($\epsilon$); and the forefeet by the stars Beta ($\beta$), Eta ($\eta$), Pi ($\pi$); and Lambda ($\lambda$) to Kappa ($\kappa$). The shoulders and body are represented by the "great square," the stars Alpha ($\alpha$), Gamma ($\gamma$), and Beta ($\beta$) of PEGASUS and the Alpha ($\alpha$) of ANDROMEDA. As is the case with many of the constellations, the figure is not complete.

From the square of PEGASUS, ANDROMEDA [1] stretches in an almost straight line; see p. 54. Lower down are TRIANGULUM, the TRIANGLE [395]; ARIES, the RAM [30]; and PISCES, the FISHES [320]—not to be confused with PISCIS AUSTRINUS of which we have already spoken. The stars of PISCES are faint, but an imaginary line from Alpha ($\alpha$) to Beta ($\beta$) in ARIES, if continued onward, will cross the two lines of stars which meet at a point and form the eastern end of the constellation. Farther toward the west, or to the right, the other termination of the group is formed by the pretty chaplet of stars at Theta ($\theta$), Lambda ($\lambda$), Gamma ($\gamma$), etc. Many of these stars are too faint, except on very clear nights, to be seen without an opera-glass. Alpha ($\alpha$) is the brightest object of the constellation. In some of the ancient atlases the stars from Alpha ($\alpha$) to Eta ($\eta$), etc., marked the "Eastern" Fish, those at the chaplet the "Western" Fish, and the stars from Mu ($\mu$) to Omega ($\omega$) represented a ribbon or garland binding them together.

Near the Alpha ($\alpha$) of PISCES lies the head of the huge constellation called CETUS, the WHALE [110]. The creature's head is formed by the stars Alpha ($\alpha$), Lambda ($\lambda$), Mu ($\mu$), Gamma ($\gamma$), etc., and his great tail stretches downward and westward to Beta ($\beta$).

We have already noted the first-magnitude star FOMALHAUT [331]—directly to the south. A little to the west, and just above, is the constellation CAPRICORNUS, the SEA-GOAT [75], with stars so faint as to be almost invisible except upon a clear night. We may always find its location, see p. 28, by remembering that the "shaft of Altair"—the three stars, Alpha ($\alpha$), Beta ($\beta$), and Gamma ($\gamma$) of AQUILA [20]—points downward directly to it, just as it points upward in the general direction of LYRA, the LYRE [260]. We have already spoken of SAGITTARIUS [340], on p. 56. Above ALTAIR, as it sinks to westward, we find the small constellations, DELPHINUS, the DOLPHIN [155], and SAGITTA, the ARROW [335]; and higher, and farther to the north, is CYGNUS, the SWAN [145], marking the Northern Cross.

But, as shown on p. 28, the shaft of ALTAIR—the three stars Alpha ($\alpha$), Beta ($\beta$), and Gamma ($\gamma$) in AQUILA—does not point so directly downward as shown above; it *now* lies more nearly parallel to the horizon. Upon the other hand, the Northern Cross and SAGITTA do point downward more directly. Of LYRA [260] we have just spoken, p. 58, under our northward map. The remaining constellations toward the west are now too low in the sky for clear observation. The track of the planets lies in our present map through SAGITTARIUS, CAPRICORNUS, AQUARIUS, PISCES, ARIES, and TAURUS; see p. 80. At precisely this hour, in northern latitudes, the first of these has set; see note 10, p. 31.




KEY-MAP TO THE SKY AS THE OBSERVER FACES SOUTH.
NOV. 1, 8 P.M., OCT. 15, 9 P.M., OCT. 1, 10 P.M., SEPT. 15, 11 P.M., SEPT. 1, 12 P.M.
FOR NIGHT-CHART TO THIS MAP SEE OPPOSITE PAGE.
FOR THE SKY AS THE OBSERVER FACES NORTH, SEE PP. 58, 59.
For the sky at other Dates and Hours see Time Schedule, p. 35.

**The Telescopic Objects. For the Constellations See the Page Opposite.**

The numbers in brackets [ ] refer to corresponding numbered notes in Observer's Catalogue, p. 116.

I. WITH OPERA-GLASS OR FIELD-GLASS first examine the course of the Milky Way, lying here to the westward, at the right, and running from CYGNUS at the northwest, southward through SAGITTA, AQUILA, and SAGITTARIUS.

It will be interesting, also, to trace out the pretty chaplet of small stars formed by Theta (θ), Gamma (γ), Lambda (λ), etc., in PISCES. It is now almost due south, upward and a little to the left from the bright star FOMALHAUT. Trace, also, just to the right of this pretty figure, the little Y in AQUARIUS, which forms the mouth of the water jar.

Among the double stars that may be divided by an opera-glass or field-glass are Alpha (α) [76] and Beta (β) [77] in CAPRICORNUS; and also the star marked *6* [426] near the foot of the Cross in CYGNUS. Of the easier double stars in LYRA, and of the PLEIADES in TAURUS, we have spoken on p. 59, in connection with the northward sky. Among the smaller groups here before us, DELPHINUS and SAGITTA will be found of special interest.

II. WITH A TWO-INCH TELESCOPE first note, with eye-piece of lowest power, the objects already mentioned. Sweep through the rich sections of the Milky Way, especially in the neighborhood of ALTAIR [21] and downward toward the west, past the Lambda (λ) of AQUILA and the Lambda (λ) of SAGITTARIUS.

Among the double stars there is a fine object for a two-inch telescope in the Beta (β) [332] of PISCIS AUSTRINUS, low down but now almost directly before us to the south. An easy and beautiful double is the Gamma (γ) [157] of DELPHINUS; and even finer is the Beta (β) [147] of CYGNUS. But of this, and of the stars in LYRA, we have just spoken on p. 59. Turning now to the east, or toward the left, beautiful objects are to be found in the Gamma (γ) [32] and Lambda (λ) [31] of ARIES, and in the Pi (π) [4] and the Gamma (γ) [3] of ANDROMEDA,—though the latter are rather high for convenient study. Among the faint stars of PISCES we may try Alpha (α) [321] and Psi (ψ) [323]; and in AQUARIUS we shall find a charming object in Zeta (ζ) [17], the components being practically of the same magnitude. Note, also, the star Psi (ψ′) [18] in the same constellation.

Turning again to the westward, or to the right, we may note one of the most beautiful of the double stars in the Theta (θ) [368] of SERPENS. Though the actual slant or inclination of the lines here at the map's edge varies from the chart, the imaginary line from Zeta (ζ) to Lambda (λ) in AQUILA really leaning to the right, yet the permanent alignment of the stars is always unchanged. About half-way between these stars, therefore, the Theta (θ) of SERPENS will still be found.

III. WITH A THREE-INCH TELESCOPE, first examine the objects listed for the two-inch instrument. Using an eye-piece of low power, examine, next, the clusters marked M 2 [16] in AQUARIUS; M 15 [303] in PEGASUS—in line with Theta (θ) and Epsilon (ε); M 11 [23] in AQUILA—near the star Lambda (λ) in the Eagle's tail; and M 27 [427] in VULPECULA, almost in line with Beta (β) at the foot of the Northern Cross and the Eta (η) of SAGITTA. Among the finest is M 33 [396] in TRIANGULUM; but this, as well as the great nebula in ANDROMEDA, M 31 [2], is now rather high up for convenient observation.

Among the double stars are Pi (π) [79] and two near-by stars [78, 79b] in CAPRICORNUS. This group of small double stars is fully charted in the map of the N. Hemisphere at the location assigned in the Observer's Catalogue [79], etc. Higher up is the Epsilon (ε) [302] of PEGASUS, and to the eastward is the star Zeta (ζ) [322] in PISCES, the small object between Mu (μ) and Epsilon (ε). It is the fourth of the little stars on the westward line from Alpha (α). We may also try Gamma (γ) [333] in PISCIS AUSTRINUS. In CETUS, we may examine Alpha (α) [111], Gamma (γ) [112], Zeta (ζ) [114], and the small star marked *66* [116]. The last offers a fine contrast of colors, but in searching for the star it is well to remember that Omicron (o) [113] is a remarkable "variable," and is often invisible to the unaided eyes.

## V. Objects to be Seen: The Solar System

### The Sun

We frequently refer to starlight and sunlight as though they were different things. Strictly, however, the only light that we know anything about, on any large and important scale, is starlight; for the Sun itself is, as we have seen, a star; and thus all the light of the day is starlight. The Sun is but the nearest of the stars.

And the lights of the night are starlight, except the artificial lights that men have made. The moon shines not by its own light but wholly by the reflected light of the Sun. The planets shine, also, chiefly by reflected light. If Jupiter and Saturn be partly self-luminous, as some suppose, their brightness would be insignificant without the Sun. Even the chance comets that come into our skies, while they yield a partial glow of their own, shine chiefly by their reflection of the Sun, or because of the direct action of the Sun upon them. The "fixed" stars shine by their own light, for these—as we have seen—are other suns, many of them far larger and more luminous than ours.

Our Sun, however, is of even greater importance than all the other stars together, for the Sun gives us heat as well as light. This heat gives us not only the warmth which prevents the solid freezing of all living things, but it gives us our changes of the seasons, our clothing, and our food. There could be no vegetation without the stimulation afforded by the Sun's warmth; and without vegetation no animal life could be supported. The light received from the Sun is 600,000 times that received from the moon, and it is roughly estimated that the apparent brightness of the Sun's surface is about 150 times that of a calcium light. The heat of the Sun is so far in excess of any standard which we can secure that its very expression becomes difficult. Estimates vary. Said the late Prof. C. A. Young of Princeton University—in quoting one of the best authorities on the subject—its "'effective temperature' comes out about 7000° C., or 12,000° Fahrenheit." "Or," says Professor Young himself—in illustrating the solar radiation at the Sun's surface—"if a bridge of ice could be formed from the earth to the Sun by a column of ice 2.1 miles square and 93,000,000 miles long, and if in some way the entire solar radiation could be concentrated upon it, it would be melted in *one second*, and in *seven more* would be dissipated in vapor."

But of the light and heat sent out by the Sun, the earth receives only $\frac{1}{2,200,000,000}$th part. For the earth is not only a very small body as compared to the Sun; it is, also, very far distant. These factors in the case are difficult to realize, if merely set down in figures. Let us, therefore, fall back on some familiar comparisons. The Sun is 1,300,000 times larger than the earth. A railway train that could make the circuit of the earth in 30 *days* would take over 8½ *years* to make the journey round the Sun. If 109 globes as large as the earth were put edge to edge and if the surface of the Sun were flat, their long line would just reach across the Sun's face. When we look at our moon it is hard to realize that it is about 240,000 miles away. The diameter of the circle it describes is thus approximately 480,000 miles. Yet the Sun is so large that the moon could revolve in its orbit, if earth and moon were put *inside* the Sun, and there would be much room to spare, for the real diameter of the Sun is over 866,000 miles.

**THE SUN AT TOTAL ECLIPSE**

*Showing corona and prominences; from a photograph taken, Jan., 1898, at Jeür, India, by Dr. W. W. Campbell, Director of the Lick Observatory*

The facts as to the constitution of the Sun are of great interest, but their full description belongs to a manual of astronomy rather than to a simple manual of observation. To the beginner the chief objects of interest on the Sun's surface are the *sun-spots* and the *faculæ*. The sun-spots have usually been regarded as cavities or holes in the photosphere, — the *photosphere* is the cloud-like covering of intensely heated matter which enfolds the Sun's surface. The *faculæ* are best seen near the Sun's limb, the "limb" being the edge of the disk, but they are found like streamers or ridges of intenser light over the whole surface of the Sun; they are especially active in the region of the sun-spots. They are from 1000 to more than 40,000 miles in length and from 1000 to 4000 miles broad. The faculæ should not be confused with the *prominences* or *protuberances*, which, when eruptive in nature, shoot like the spray of colossal fountains to heights of from 100,000 to over 300,000 miles. The velocity of their outward rush is in some cases as high as 600 miles a *second*. These may usually be seen only with the aid of the spectroscope; see Fig. 10, p. 68. They may also be observed and photographed during an eclipse of the Sun; see p. 63. Even a small telescope, however, will show us the faculæ and the sun-spots. The latter are the more interesting and the more easily observed.

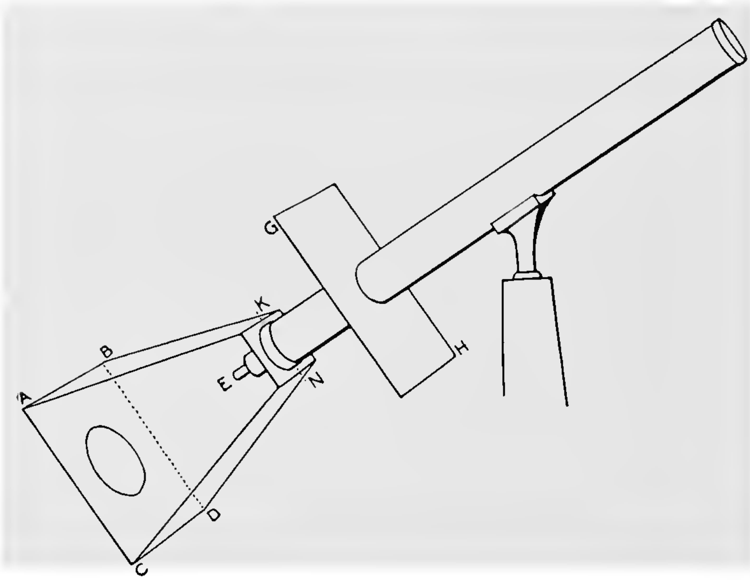



*Fig. 5. Projecting the Sun's Image on Screen.*

Warning must at once be emphatically given against any attempt to view the Sun without some special protection for the eye. Three methods are available. A small protective cap of dark-colored glass, sometimes called a "sun-glass," is usually provided with one of the astronomical eyepieces. This may be safely used, in directly viewing the Sun, on instruments as large as three inches in aperture, *provided* the telescope is turned away from the Sun at frequent intervals. Such a precaution is necessary not only to spare the eye, but to prevent the heat of the Sun from cracking the eyepiece. These small sun-glasses may also be used on larger instruments but with a risk proportionate to the increase in size of the telescope. More than one astronomer has lost an eye by taking injudicious risks in solar observation. A special attachment, called the "Herschel" eyepiece, much reduces both risk and inconvenience. In this way the Sun's rays are reflected at right angles by a plane of unsilvered glass, most of the light and heat passing harmlessly out of the open end of the device. While this method greatly decreases the amount of heat and light reaching the eye, there is still need for the protecting cap of darkly tinted glass over the eyepiece proper. The glass need not now be so dark, however, as when the Herschel attachment is not employed.

By far the best method for observing the Sun and for properly following the spots is shown in Fig. 5. This is not intended as a formal design, but merely as the general suggestion of a method. It may be elaborated or simplified according to the size of the tele-

scope and the resources of the observer. The square G H is merely a cardboard shield slipped over the telescope to prevent the direct rays of the Sun from obscuring the image projected on the screen, A B C D. The rods supporting this screen may be of bamboo cane, or stiff wire. The collar at K N should be free enough to permit the frame to be

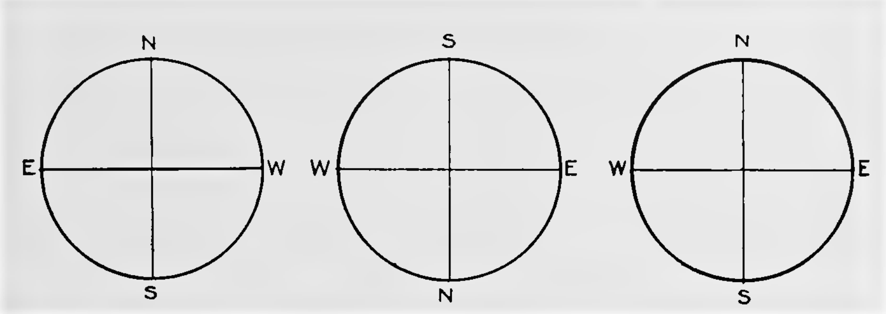



*Fig. 6. Orientation of the Sun's Image.*

*At left, as seen with naked eye; at centre, as seen in astronomical telescope; at reader's right, as seen when projected on a screen.*

moved a little up or down on the tube of the telescope. An approximate focus may be obtained by merely holding a white card behind the telescope, moving the eyepiece E a little in or out as required. If the frame disturbs the balance or poise of the telescope on the tripod, a make-weight may be hung on the large end of the tube; or the tube, between N and G H, may be rested on the back of a chair. The image of the Sun may be shown more clearly if a dark cloth be thrown over the top and the farther side of the screen, A B K D. The image may then be viewed from *this* side of the screen. The sun-spots may not only be well seen, and drawn and recorded for future comparisons, but a number of observers may view them at the same time,—if there be any spots there! A sun-spot maximum will occur in the year 1915, and thereafter at intervals of 11.13 years. They are likely, however, to be present at any time; but they are not *always* present, and if the telescope does not show them, it is not necessarily the fault of the instrument. They may sometimes be seen with the unaided eye, either near the time of sunset, or, during the day, through a large piece of colored glass. The observer may always know that any spots that can be seen with the naked eye are at least four times the size of our earth.

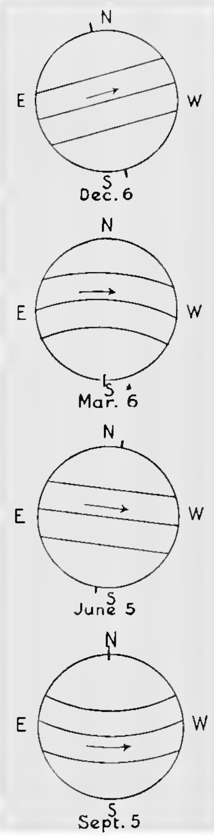



*Fig. 7. Course of the Sun-spots.*

As the Sun, like the earth, has "points of the compass," it is well for us to note these at once. They are here shown in Fig. 6—the disk to the reader's left representing these directions as they *are*, or—in other words—as they appear when the Sun is viewed with the naked eye or in an opera-glass. The central disk shows these directions as they appear in a telescope with astronomical eyepiece; the disk to the reader's right shows the Sun as it appears through such an eyepiece when the image is projected on a *screen*, as in Fig. 5. From Fig. 7 we may see that the axis of the Sun is sometimes tipped a little to right or left, as we face toward it, and that the path of the sun-spots shows a somewhat different inclination at different periods of the year. The observer should bear in mind that the Sun is shown in Fig. 7 with the image "erected" or as viewed with the naked eye. Fig. 6 will therefore show how to make the required mental adjustment for the astronomical eyepiece, whether the image be viewed directly or projected on a screen.

As we note the course of the sun-spots, we seldom find them exactly at the Sun's equator or near the poles. They are usually seen in the regions lying midway between the poles and the equator, coming into view at the eastern limb (our left as we face southward), passing out of view at the right in about fourteen days, and sometimes (after as long an

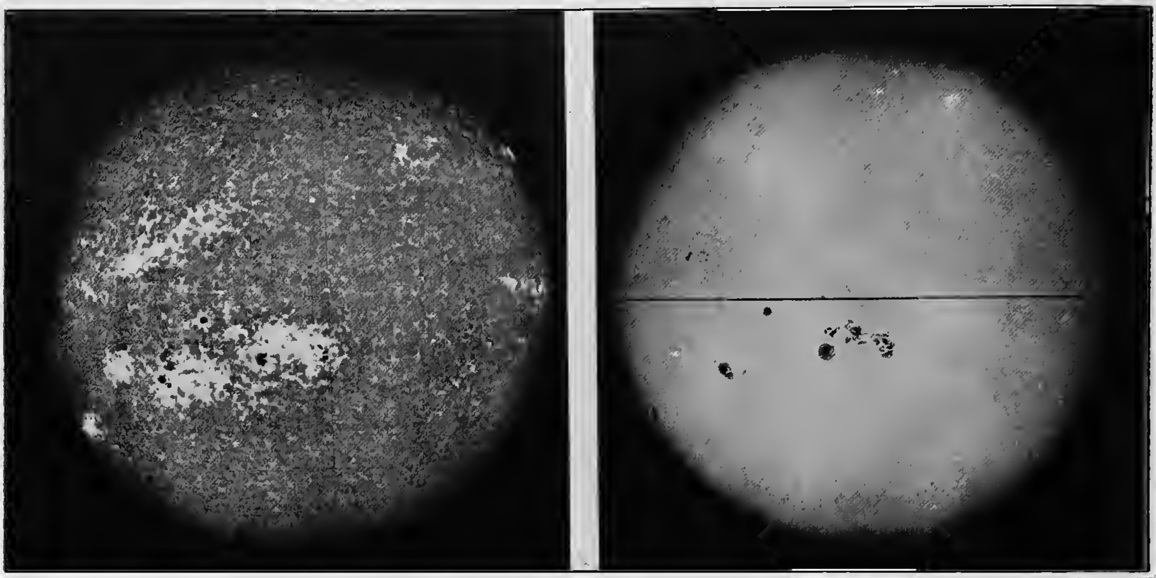


FIG. 8. THE DISK OF THE SUN

*Comparison of direct photograph, at reader's right, with high-level spectroheliogram, on left*
*From negatives made at the Yerkes Observatory*

absence) reappearing at the eastern limb. We can thus prove to our own satisfaction that the Sun rotates on its axis, as does the earth, and that its period of rotation is approximately twenty-seven days, as viewed from the earth. The period of rotation is a little shorter near the Sun's equator than to the north or south of it, for the gaseous masses of which this great whirling globe is composed seem to move somewhat more slowly as we look toward the poles.* In our engraving marked Fig. 9, we can trace the course of a group of spots across the Sun's disk; and in the upper half of the sections which compose that illustration we may trace the life of a sun-spot as it grows in magnitude. In Fig. 8, in the image to the reader's right, the dark centre of the spots (note, for example, the largest spot there shown) is called the *umbra* (or shade); the half-shade that seems to bound the umbra is called the *penumbra;* within the umbra there may sometimes be seen a still darker "core" called the *nucleus.* The expressions "dark" and "darker" and "shade" are used, of course, only in a relative sense; for the very darkest spot on the Sun is always

* Not only has the Sun, like the earth, a motion on its axis, but it has a motion in space. At a velocity of about 12 miles per second (over 720 miles a minute) it is carrying the whole solar system in the general direction of the bright star Vega (see p. 38). This point is called "the apex of the Sun's way." The conclusions as to the direction of the Sun's motion have not been invalidated by the investigations of Kapteyn, as some text-books assume; for while Kapteyn and others have shown the possible existence of a double star-drift, the new facts have been found to lead substantially to the old conclusion. There has always been some slight disagreement among astronomers as to the precise direction represented by the "apex," but all these estimates place the point fairly near the star Vega. The exact position according to Boss (1910) is R. A. 18 h. 2 min.; D. +34°; according to Hough and Halm, R. A. 18 h. 4 min.; D. + 26°. For recent expressions on the direction of the Sun's motion, the advanced student may wish to refer to *British Ass. for the Advancement of Science; President's Address*, 1907, by Sir David Gill, K.C.B., LL.D., F.R.S., etc., p. 19; Newcomb-Engelmann, *Pop. Astron.*, 4th edition, ed. by Prof. Dr. P. Kempf, of the Astrophysical Observatory, Potsdam, pub. Leipzig, 1911, p. 535; and especially to *Les Courants Stellaires*, par M. P. Puiseux, Astron. de l'Obs., Paris, Président de la Société Astronomique de France; *Bulletin de la Soc. A. F.*, July, 1911, p. 303.

brighter, by many times, than any light we can create by artificial means. The umbra of a sun-spot, if a very small one, may be 500 or 600 miles in diameter; the diameters of the larger ones are from 30,000 to 50,000 miles; and the penumbra surrounding a group of spots is sometimes 100,000 miles in width. Note also in Fig. 8, the image on the reader's

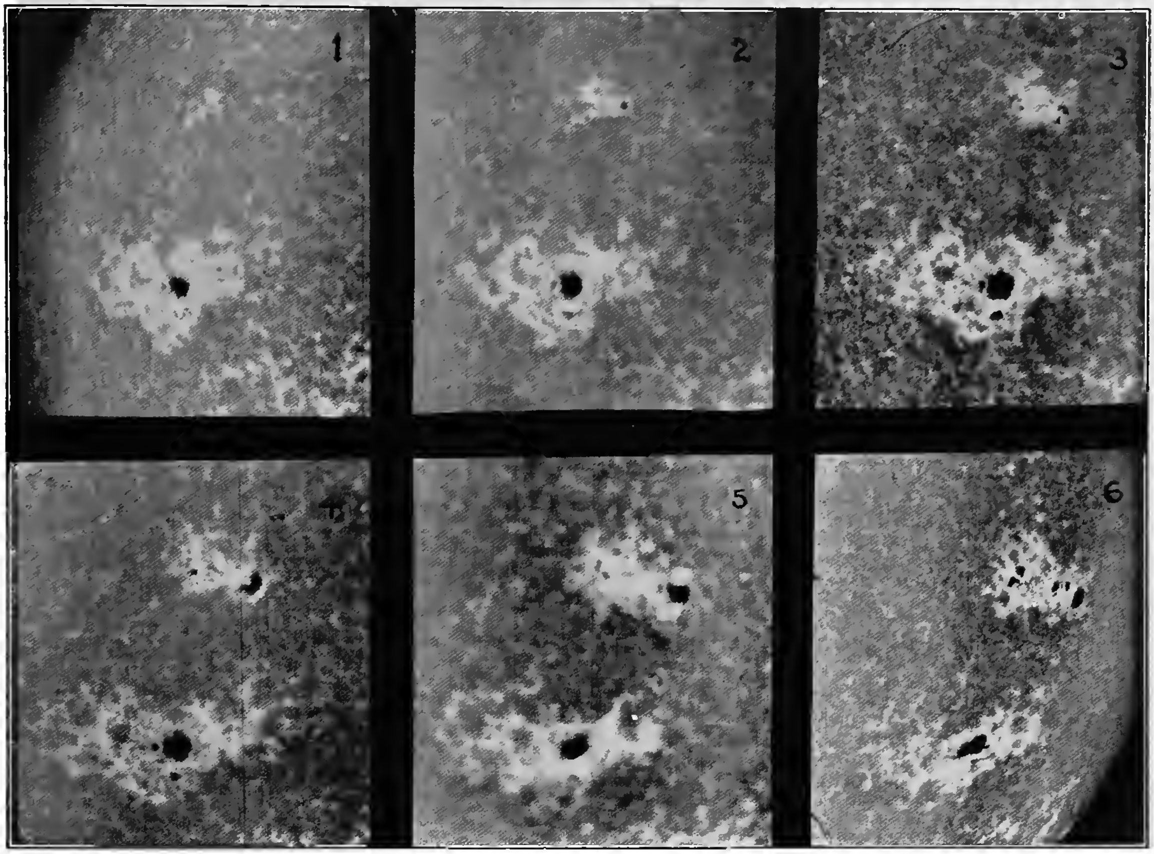



FIG. 9. SHOWING DEVELOPMENT OF SPOT AND ROTATION OF SUN

*From spectroheliograms made at the Yerkes Observatory*

left. Here we have a picture of conditions at a higher level of the Sun's atmosphere than shown on the right, but at the same moment. We note the same spots, but the spectroheliograph enables us to see near them the brighter clouds of calcium vapor called the *flocculi*. These lie above the *faculæ*, see p. 64, and seem to arise from them or to crown them—as white crests will often crown the waves of a stormy sea.

In one case the lifetime of a sun-spot was eighteen months (1840–41) but the period of duration, even for large ones, is usually from two months to three, and they sometimes persist for only a few days; though a new spot may sometimes break out in the same quarter of the Sun from which a spot has disappeared. An active spot will often exhibit marked changes within as short a period as twenty-four or thirty-six hours, and simple drawings which exhibit the state of such an object from day to day become interesting and useful records.

The *corona* is visible only at the time of the Sun's total eclipse by the moon. This, as may be seen by the photograph reproduced on p. 63, is a beautiful halo or glory completely surrounding the solar sphere. At the edge of the Sun's disk, during such an eclipse, the prominences may also be seen—shooting like brilliant sheets or tongues of flame up

into the light of the corona. As eclipses of the Sun recur very infrequently at any particular point, and as the breadth of the shadow at totality averages only about 70 miles, they may be regarded as rare phenomena. Expeditions are sent great distances for the purpose of observing them.

FIG. 10. ERUPTIVE PROMINENCE AT THE SUN'S LIMB

*From negative made at the Yerkes Observatory*

One reason why it is so hard for us to appreciate the great size of the Sun is that the Sun's actual distance from us is so great. We call it roughly 93,000,000 miles. But what do such figures mean? Says Professor Holden, formerly of the Lick Observatory, "Sound travels fast. It takes time; you see the flash of a distant gun before you hear the report. It travels 1100 feet a second. . . . But, if a sound were made in the Sun, and if a sound could travel through the empty spaces where there is no air (which it cannot do), it would not reach the earth till fourteen years afterward. If a cannon-ball could be fired in the Sun straight at the earth, you would first [in 8.3 minutes] see the *flash* [except that the brilliancy of the sun would prevent]; nine years afterwards the ball would reach the earth, and five years after that you would hear the sound."* Indeed, if an infant

* For the popular and yet scientific statement of the facts as to the distance, dimensions, and constitution of the Sun, see the volumes by Young, Todd, Lockyer, and Holden named in the bibliography on p. 144. See, also, *A Study in Stellar Evolution*, G. E. Hale, University of Chicago Press, 1908; and *The Sun*, by Charles G. Abbot, Director Smithsonian Astrophysical Observatory, D. Appleton & Co., 1911.

could put out his hand to-day and touch the Sun—assuming that his arm were as long as the distance between Sun and earth,—he could never feel the pain the heat might give, for he would die of old age before the nerves, despite the high rapidity with which they transmit sensations to the brain, could report the fact of contact. More than 100 years must elapse for the transmission of the message. If, over distances so great and under the difficulties imposed by the Sun's light and heat, the beginner cannot add greatly to his stock of knowledge, there is little reason to complain. The wonder, rather, is that we may learn so much; and that even with the smallest instruments we can so readily prepare ourselves for further study.

## The Moon

### OUR NEAREST NEIGHBOR

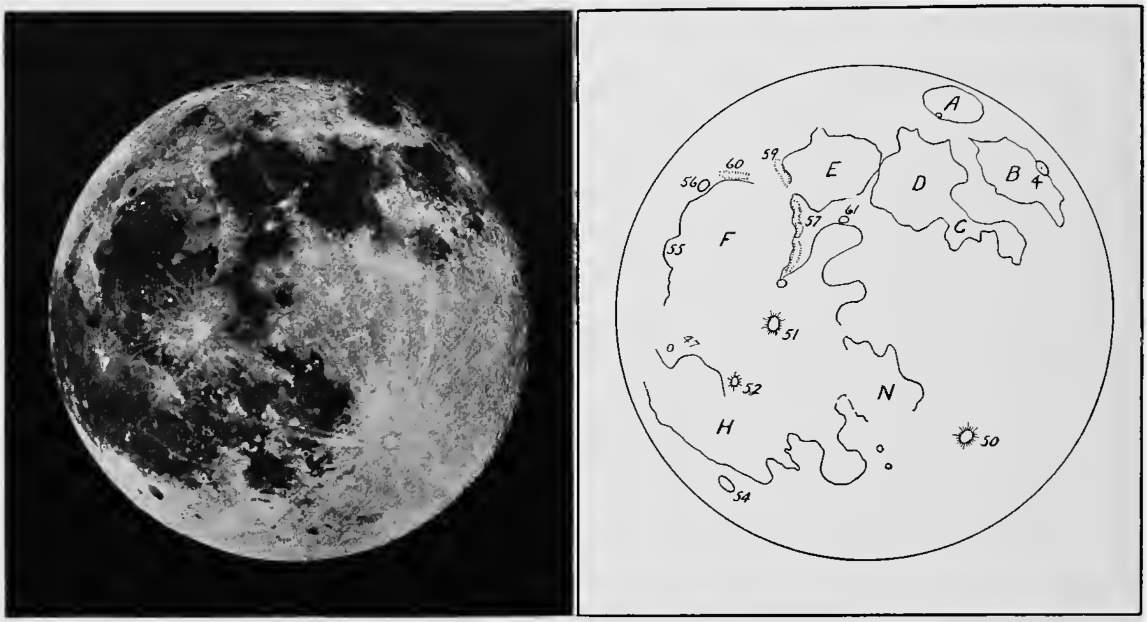
We now pass to what is perhaps the most interesting and charming of all the objects for a small telescope. The moon's diameter is 2162 miles, about one-fourth the diameter of the earth. As its distance from us is but 240,000 miles, a magnifying power of 60 will be sufficient to diminish its apparent distance to 4000 miles. From two to three hundred different features upon its surface can thus be brought into clear relief, and the use of still higher powers will reveal an even greater measure of detail. The lunar "seas," "craters," and mountain ranges may be studied, even by the veriest novice, with real satisfaction.

*Old Moon in New Moon's Arms*

First, however, let us remember that even for the unaided eyes, the moon is a far finer and lovelier object than we usually realize. Instrumental aid, whether opera-glass, field-glass, or telescope, should not destroy the interest of the moon as it appears to our ordinary vision. Indeed, this interest should be thus increased. The use of instruments may help us to see more freely and clearly the objects on the moon's surface, but when these are once known, the naked-eye moon should become more fascinating than before, for we can now identify many of the objects that we should probably not have noted at all. Instead of merely watching for the fantastic shapes of the Man in the Moon, the Lady in the Moon, the Rabbit in the Moon, etc., etc. (all very harmless and amusing occupations), we can learn increasingly to recognize the larger shapes and outlines of actual lunar formations. The moon's "geography" is easily acquired. Indeed, the eye may readily be trained to recognize some of its bolder features even by daylight. It was this use of his natural mental and optical equipment that enabled Leonardo da Vinci—painter, architect, engineer—to reach the true solution of "the Old Moon in the New Moon's Arms." He discovered, more than a hundred years before the invention of the telescope, that the faint soft light thus seen on the surface of the old moon was the result of illumination from our earth itself.

For the moon is not self-luminous. It shines by reflected light alone. This reflected light is chiefly that of the Sun. Here in our small illustration, the brighter light comes therefore from the Sun, and, striking the globe of the moon from the west, makes the brilliant crescent shape called the "new" moon. This, from our viewpoint, is the lunar sunrise. As the period of the moon's revolution in its orbit round the earth is exactly coincident with the period of its revolution on its axis, the *same* side is always turned toward us. But

upon this side, we may see the increase of the lunar day as the Sun's rays light up more and more of the moon's surface. In the illustration on p. 73 we may see the advance of the Sun at 2 days; on p. 75 the Sun's advance at 6 days; on p. 77 at 9¾ days; on this page at 14½ days. Here, the moon is said to be full. During the latter half of the month, the




**THE MOON AT FOURTEEN AND ONE-HALF DAYS**

*Image erected; for Study with Opera-Glass or Field-Glass, or with Telescope using Terrestrial Eyepiece*

side of the moon toward us catches daily a little less of the Sun's light, the long lunar sunset begins, black night falls upon the "sunrise side"—the side to the observer's right,—and the objects which were lighted from the west now seem to be lighted only from the east.

We can see at once, moreover, that while the full moon represents the phase of most brilliant illumination, it shows us less detail than we find in our other illustrations. This is because the Sun's light now strikes the moon directly. We are enabled to see the objects on the moon at their best, only as they are brought into clear relief by their *shadows*, and we see the full moon so imperfectly because in the Sun's direct illumination the shadows are largely destroyed. Still, there are obvious distinctions and contrasts, at least for the larger features, and we are certainly enabled to get a simple general view of the whole earthward side. I have therefore chosen this view of the moon for our first study. The image is here presented as viewed with the naked eye, the opera-glass, field-glass, and spy-glass,—or through the telescope, if used with a terrestrial or erecting eyepiece.

Upon the moon as here shown, we may first note that certain tracts or areas are much darker than others. These darker spaces, as we may see even in an opera-glass, are depressions in the moon's surface, lying somewhat lower than the surrounding region. They were called "Maria" or "Seas" by Galileo and were among the objects first shown to the poet Milton at the time of his visit (1638) to the Italian astronomer.* They contain no water,

* ". . . the Moon, whose orb
Through optic glass the Tuscan artist views
At evening from the top of Fesolé,
Or in Valdarno, to descry new lands,
Rivers or mountains in her spotty globe."

Milton, *Paradise Lost;* Book I.

for the moon has no water and practically no atmosphere, but the early name has been preserved. They are large, low-lying, gray plains, here and there marked by ridges and small crater-like formations. The one which is most perfectly enclosed is marked A in the Key-Map. This is *Mare Crisium*—the Sea of Crises, or Sea of Conflicts; dimensions about 70,000 square miles; 280 miles long; 360 miles wide (east to west). The latter dimension seems the smaller in a telescope,—this is an optical illusion, due to foreshortening. The object marked B is the Sea of Fecundity,—*Mare Fecunditatis;* that marked C is the Sea of Nectar,—*Mare Nectaris;* D is the Sea of Tranquillity,—*Mare Tranquillitatis;* E is the Sea of Serenity,—*Mare Serenitatis;* F is the Sea of Showers,—*Mare Imbrium;* H is the Sea of Storms,—*Mare Procellarum;* N is the Sea of Clouds,—*Mare Nubium.* These "seas," particularly A, B, D, and E, may often be distinguished with the unaided eyes. The Sea of Conflicts (A) may sometimes be clearly seen by daylight. As the moon is here shown, this object lies nearer the top of the picture than is usually the case. Compare its position as shown on pp. 73, 75, 77. Note, however, that in these the moon's image is inverted, for study with an astronomical eyepiece.

Let us now note some of the larger mountain ranges. The longest and most impressive is No. 57, the Apennines,—bordering the Sea of Showers. Just above, and across the strait between F and E, the range marked 59 is called the Caucasus Mountains; and to the left, the Alps are numbered 60. Near them, at No. 56, is a great walled plain called Plato, 60 miles in diameter. No. 55 is the Bay of Rainbows,—*Sinus Iridum*, one of the most beautiful features in the "coast-line" of the Sea of Showers.

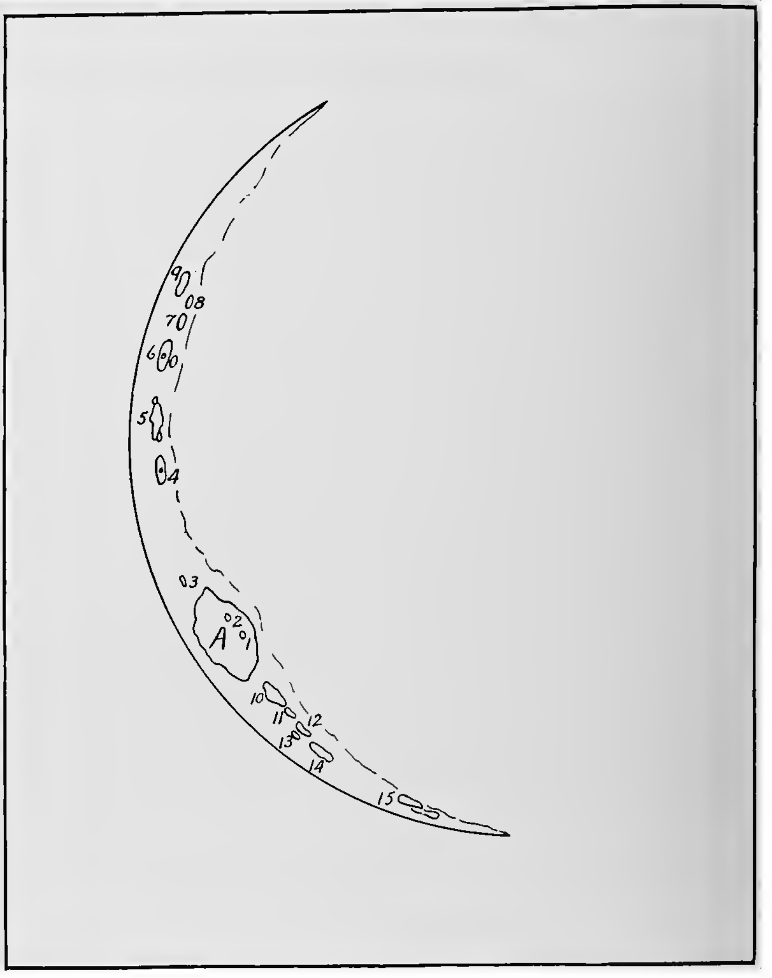
The most conspicuous of the great lunar "craters"—so called on account of the volcanic appearance of their structure*—are Tycho, No. 50; Langrenus, No. 4; Copernicus, No. 51; Kepler, No. 52; Aristarchus, No. 47; and Grimaldi, No. 54. Because of the direct illumination of the Sun, these are now visible chiefly as brilliant patches of light—Aristarchus is the brightest spot on the moon, Grimaldi the darkest—but in our other maps we may see some of them under different illuminations. From the region near Tycho, No. 50,—which Webb calls "the metropolitan crater of the moon,"—radiates the most conspicuous of those systems of light-streaks or light-rays which have proved such an insoluble problem to the astronomer. They give to the moon at this time what some one has called the appearance of a "peeled orange." We refer to them again on pp. 74, 78.

Grimaldi, No. 54, is one of the largest of the "wall-surrounded" plains, extending 148 miles N. to S. and 129 miles E. to W., covering about 14,000 square miles. Kepler, No. 52, is also a ring-plain, though smaller—about 22 miles in diameter—and very much brighter. A peak on its eastern border attains a height of 10,000 feet. Brighter still is Aristarchus, No. 47;—so brilliant, indeed, that it may often be seen long before the *terminator* reaches it, shining like a faint but obvious beacon in the waste of the lunar night.

The *terminator* is the division-line between light and darkness on the moon's surface. The advance of the terminator marks the progress of the lunar day. The moon when full shows, of course, no terminator, but in our illustration of the moon at two days—shown on the next page—it has advanced just beyond A, the Sea of Conflicts. There be careful to note that we show the image of the moon *inverted*, as seen in a telescope with an astronomical eyepiece. The object A seems, therefore, to be low down to the left instead

* Next after the "seas" and mountains, the larger lunar formations, especially those having an appearance suggesting volcanic origin, are called *walled plains;* the deeper of these—smaller, more definite, and more circular in form—are called *ring-plains;* and the ring-plains are also often called *craters.* These terms are all applied with a good deal of freedom; inasmuch as the real origin of the formations is still a mystery. The objects on the moon were named largely by Riccioli (1651), in honor of various personages, astronomical and otherwise—as "Copernicus," "Kepler," etc. Some of this terminology is utterly fanciful and has no excuse for existence except that it is established.

of upward to the right; and in dealing with the lunar objects from this point onward the directions, etc., will be given for the moon as so viewed and as so represented in our larger engravings. The later of these are clearer in detail than the present, for the very new moon lies too near the horizon for sharp definition. Its objects show far more distinctly in a small telescope than in this photograph. Of the Sea of Conflicts (A) we have already spoken, p. 71; but we may now note within it two or more small craters. One of these, No. 1, is called Peirce. Another, larger, crater is called Picard, No. 2, and is 21 miles in diameter, with a small central mountain. On Firmicus, No. 3, have been noted slight periodical changes which to some have suggested vegetation; doubtful. Firmicus is the lower of the two small formations faintly shown in the photograph. Upward from it, slightly to the right, is Apollonius. Both are ring-plains. Langrenus, No. 4, is a superb walled plain, with walls from 8000 to 10,000 feet high, enclosing an area 90 miles long by as many broad. Its central peak rises to a height of more than 3000 feet. Vendelinus, No. 5, is not so sharply outlined in our photograph, its walls being lower and its formation more irregular, but it covers an area almost as large. Petavius, No. 6, is even larger than the preceding. The smaller formation at the right is called Wrottesley; and on this side the border of Petavius rises to 11,000 feet. A deep sharp cleft running from almost the centre of Petavius upward toward the right seems to have been first noted by the German observer, Schroeter, Sept. 16, 1788. One peak of the central mountains here reaches a height of 6000 feet above the floor. Snellius (No. 7) and Stevinus (No. 8) are also ring-plains, the former 50 miles in diameter, the latter a little larger—though showing smaller in our photograph. In Furnerius, No. 9, we have another walled plain almost as large as Langrenus, though more irregular in form.



**KEY-MAP TO THE MOON, AT TWO DAYS**

*See accompanying text, with illustration opposite*

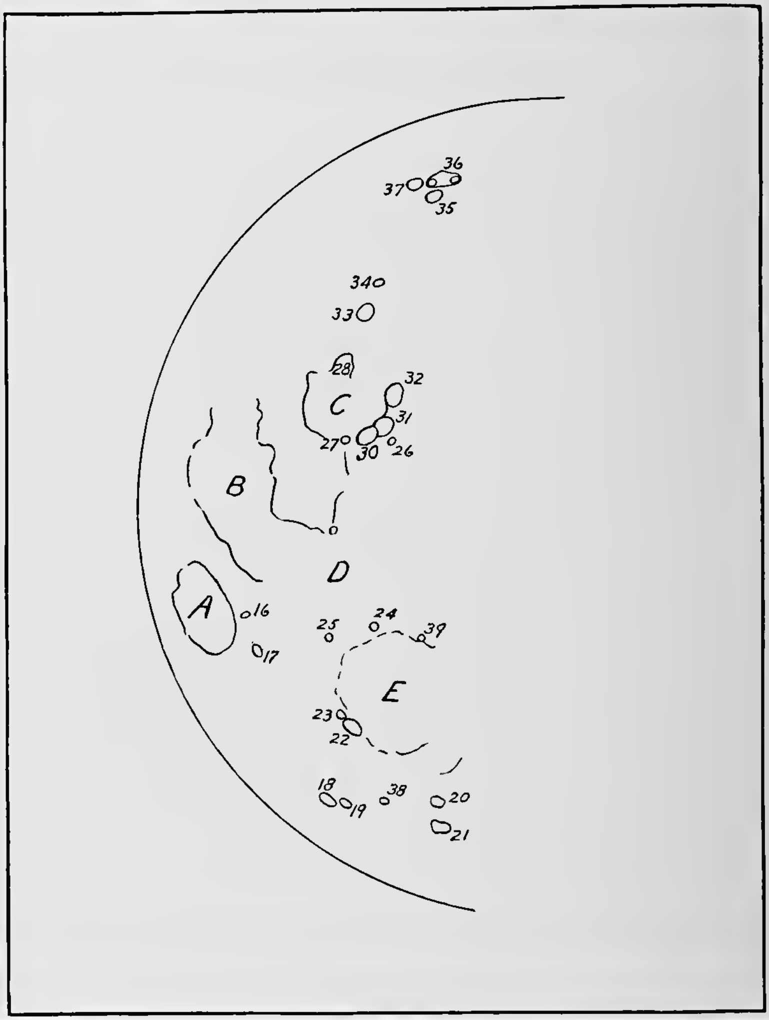
Returning to the region of the Sea of Conflicts (A) we note to the north (remember that in our map south is above, north below, as in an astronomical telescope) the fine formation called Cleomedes, No. 10. It is oblong in shape, about 78 miles in diameter, and

its huge walls rise from 8000 to 10,000 feet above the floor. Just below, No. 11, is Burckhardt, 35 miles in diameter, chiefly characterized by the great relative height of its eastern wall (observer's right), which rises to nearly 13,000 feet. The objects Nos. 12 and 13 are two ring-plains called Geminus and Bernouilli, the former being the larger, with a diameter of 54 miles. Messala, No. 14, is not so clearly marked, its roughly circular border being very irregular; its diameter is about 70 miles. Even larger, however, is No. 15, Endymion, one of the most clearly marked of the walled plains in the very young moon. Its great walls are crowned by superb peaks, attaining, in some instances, heights of 10,000, 12,000, and 15,000 feet. In following the "geography" of the moon with the aid of direct photographs, the author wishes it were possible to present a photograph for each hour of the moon's age. But the limits of space demand a selection at wider intervals. The illustrations have been so chosen, however, as to indicate all of the more important formations. For the beginner this is sufficient. Indeed, the multiplication of detail—just at the first—is confusing rather than helpful. Most of the objects shown in our picture of the moon at two days may be seen quite as well—in some cases even better—on the third and fourth days, and yet again in the lunar sunset when the moon is old, the light then striking these objects at quite another angle. The illustration of the moon at six days will serve fairly well not only for the fifth and sixth days but for several days thereafter; and when this ceases to be sufficient that for the moon at nine and three-quarter days will begin to be of service. This will in turn be sufficient, for all ordinary purposes, till the chart of the full moon, p. 70, is more appropriate. The use, there, of the terrestrial eyepiece to which that photograph is adapted, is, for the beginner, a positive advantage. For as the moon becomes fuller and brighter the additional lenses of the erecting eyepiece serve to cut down the excessive light. Theophilus, Cyrillus, and Catharina—shown so finely as objects 30, 31, 32 in the six-day moon—appear again, and quite as strikingly, in the moon at 18 and 19 days; but the "old" moon rises late.

THE MOON, AT TWO DAYS

*Image Inverted, as in Astronomical Telescope; see Key-Map opposite*

We have already spoken of the lunar seas marked A, B, C, D, E, and of the other formations from No. 1 to No. 15. Nos. 16 and 17, not far from the border of the Sea of Conflicts (A), are called Proclus and Macrobius. The former is, next to Aristarchus,—No. 47, see p. 71—the brightest object on the moon's surface and the apparent centre of a small but brilliant system of light-streaks such as we find at Tycho and Copernicus. A close examination of our photograph will show these radiations extending into A. Macrobius is less brilliant and therefore more clearly seen; diameter 42 miles, border 13,000 feet above the floor. Lower still in our picture is the fine pair, Nos. 18 and 19, called Atlas and Hercules—very boldly marked and easily observed. Atlas is 55 miles and Hercules 46 miles in diameter; the altitude of the enclosing borders is in each case about 11,000 feet. In the ring-plains, Eudoxus, No. 20, and Aristotle, 21, we have a pair still finer. Their diameters are, respectively, 40 and 60 miles, and their bordering walls also reach heights of about 11,000 feet. As to Aristotle, Elger says, "The formation presents its most striking aspect at sunrise, when the shadow of the west wall just covers the floor, and the brilliant inner slope of the east wall with the little crater on its crest is fully illuminated." Almost on a direct line between Nos. 20 and 19 lies No. 38, Burg—only 28 miles in diameter but with a brilliant interior mountain. The two other small, sharply defined ring-plains above and to the left of Burg are Mason and Grove. To the right of Mason, in duller outline, is Plana. On the very border of the Sea of Serenity (E) lies the superb walled plain Posidonius, No. 22,—often better lighted in the six-day moon than in this photograph,—and next to it, Chacornac, No. 23. Posidonius is one of the finest of lunar objects, for while its walls are only about 6000 feet high, its central crater rises from a brilliant floor on which, with a good instrument, one may find the remains of an older rampart. Between No. 24 and No. 25, Pliny and Vitruvius, seems to flow the broad strait which unites the Sea of Serenity (E) with the Sea of Tranquillity (D). Pliny is 32 miles in di-




**KEY-MAP TO MOON, AT SIX DAYS**

*See accompanying text, with illustration opposite*

ameter, Vitruvius 19. The small ring-plains, Kant (26) and Maedler (27), lie to the east and west respectively of Theophilus, No. 30.

Theophilus, 30; Cyrillus, 31; and Catharina, 32;—this triple group forms one of the really magnificent spectacles of the moon. When the moon is 5½ to 7½ days old, or when 18 to 20 days old, they may be clearly distinguished even by a small spy-glass or field-glass, if the glass be steadily held. Of these great ring-mountains Catharina is largest in area, its diameter being over 70 miles from N. to S. Cyrillus is chiefly marked by the narrow pass which opens outward toward Catharina. Theophilus is the deepest of the three—probably the deepest on the moon—being enclosed by a rampart which rises at one point to 18,000 feet. Its diameter is 64 miles. Its fine central mountain covers an area of 300 square miles and rises to a height of 6000 feet above the floor.

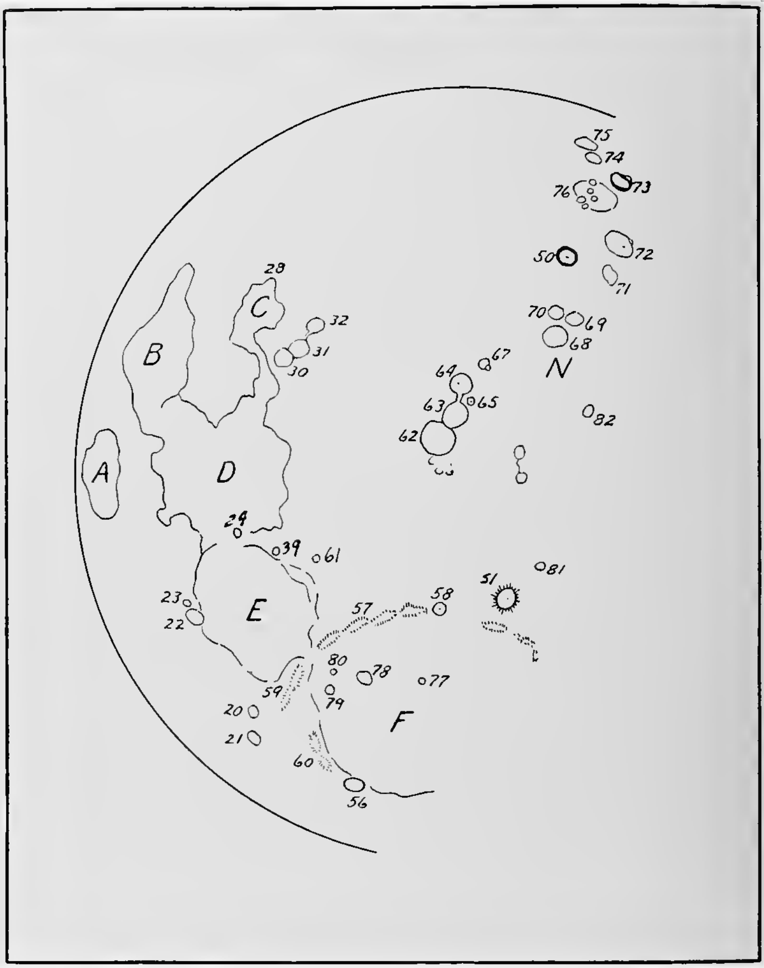
**THE MOON AT SIX DAYS**

*Image Inverted, as in Astronomical Telescope; see Key-Map opposite*

No. 28, Fracastorius, now opens like a great bay at the shores of the Sea of Nectar (C); but it is apparently the remains of an older formation, a ring-mountain now destroyed. Piccolomini, No. 33, is just above it in our picture, diameter 57 miles. Above this is Stiborius, No. 34, smaller but deeper; and higher still is the group 35, 36, 37,—Pitiscus, Hommel, and Vlacq. I follow Webb's (Beer and Maedler) map here rather than Elger, as it seems more clearly related to the photograph. The whole region is much broken, but the group can usually be identified by Hommel, with the two smaller ring-plains which it includes.

In noting the height of the lunar formations it is well to bear in mind the fact that their *relative* altitude is far greater than the actual measurements can indicate. The heights of some of our own mountains are, Mont Blanc, 15,775 feet; Mt. McKinley, Alaska, 20,464 feet; Mt. Everest in India, 29,000; Mt. Etna in Sicily, 10,865. The mountains of the moon are lofty even as compared with such standards; but it should be borne in mind that as the moon is a much smaller globe than our earth, its diameter being only one-fourth as great, the *relative* altitudes on the moon—as compared with its total sphere—should really be multiplied by four in making terrestrial comparisons.

Note, here, that many objects shown when the moon was six days old are now obscured by the more direct lighting from the Sun. In our preceding map, Theophilus, Cyrillus, and Catharina—30, 31, 32—were conspicuous; they are now hardly visible. They must not be confused with another triple formation, equally striking,—62, 63, 64. These are Ptolemy, Alphonsus, and Arzachel. The first is the most perfect example on the moon of the walled plain, its diameter being 115 miles and its area 9000 square miles. The second includes a bright central peak; the third is smaller than the second in diameter — only 66 miles as compared with 83 — but the surrounding ramparts are higher, rising at one point to 13,000 feet. Alpetragius and Herschel, 65 and 66, are smaller, but because of their great relative depth they are strikingly interesting; the walls having an elevation of 13,000 and 10,000 feet respectively. Thebit, 67, is of interest because of the deep crater at its N. E. edge. Of the triangular group 68, 69, 70 — Pitatus, Wurzelbauer, Gauricus—the first is of greatest interest, because of the breach in its great wall in the direction of the Sea of Clouds (N). Of Tycho, 50, we have spoken elsewhere, pp. 71 and 78; the rays are not here conspicuous but it may be best studied in the moon of the ninth and tenth days. Nos. 71, 72, are Wilhelm I. and Longomontanus, the latter a superb walled plain 90 miles in diameter, the highest peak upon its ramparts rising 13,314 feet. Clavius, No. 76, is regarded by many as the most variedly beautiful of all the lunar formations. Including an area of over 15,000 square miles, the peaks upon its walls rise at two points to at least 15,000 and 17,000 feet, and upon its great floor are at least five clearly defined craters. Nos. 74, 75, are Gruenberger and Moretus, not well placed for observation, and less interesting than the objects just noted; diameters 40 and 78 miles respectively. Within the Sea of Showers, F, we find the ring-plains—77, 78, 79, 80. The first of these, Timocharis, though only 23 miles in diameter, is the centre of one of the smaller ray systems; its floor lies some 3000 feet lower than the level of the "sea." Archimedes, 78, is a far finer spectacle though its depth below the level of the sea is not so great. Its great walls, however,




**KEY-MAP TO MOON, AT NINE AND THREE-QUARTER DAYS**

*See accompanying text, with illustration opposite*

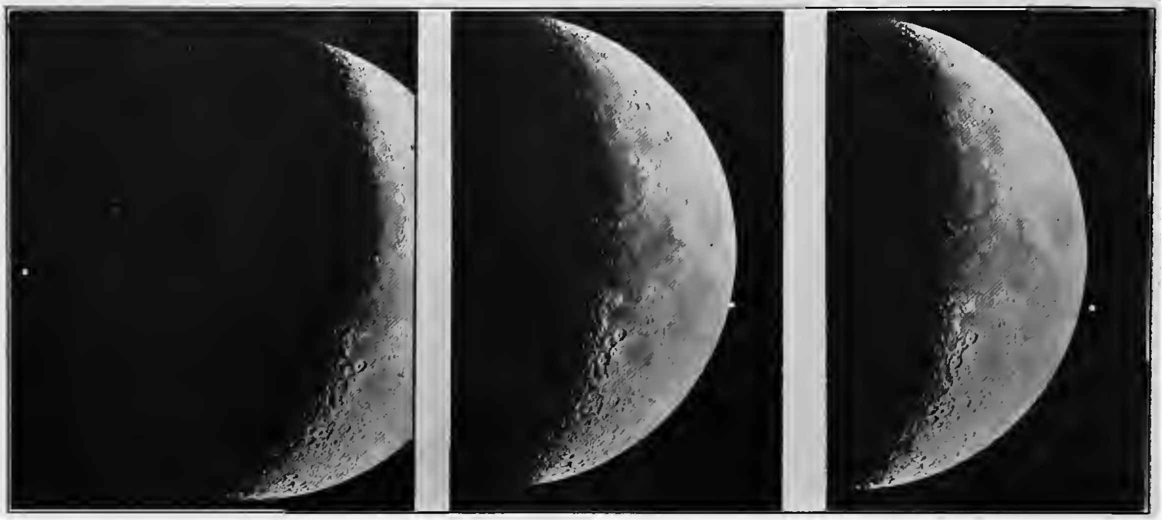
rise to a height of 4000 feet above its floor. Aristillus, 79, and Autolycus, 80, are ring-plains 34 and 23 miles in diameter, respectively,—the former having a broken and varied border and a fine central mountain. These objects, beginning with Archimedes, No. 78, are again illustrated on a far larger scale on p. 79. The reader will there find a clearer view also of such mountain ranges as the Apennines, 57; the Caucasus, 59; the Alps, 60; as well as a closer view of Plato, 56, and other objects designated in the Key-Maps on pp. 76 and 74.

**THE MOON, AT NINE AND THREE-QUARTER DAYS**
*Image Inverted, as in Astronomical Telescope; see Key-Map opposite*

Southward — or above the great Copernicus, 51— lies Rheinhold, 81; and farther still to the southward lies Bullialdus, 82,— both formations being now almost at the verge of the terminator. The former, 81, is 31 miles in diameter, its walls rising 8000 and 9000 feet; the inner slope showing a clearly marked terrace. Bullialdus is even more impressive. Its diameter of 38 miles is not remarkable, but its fine central mountain, 3000 feet in height, the depth of its interior level, 4000 feet below the "sea" in which it lies, and its enclosing walls which reach an elevation of 4000 feet, make it a finely consistent object of its class. Equally interesting is Eratosthenes, 58, at the termination of the range of mountains called the Apennines, 57. It is 38 miles in diameter, one of its peaks rising 16,000 feet. Manilius, 61, and Menelaus, 39, have similar names; but the latter, while slightly the smaller—diameter, 20 miles—has a finely marked central hill and lies directly on the Sea of Serenity, E. See, also, the enlarged photograph on p. 79.

Just below Copernicus lie the Carpathian Mountains. Copernicus itself, No. 51, is the finest of the lunar formations. Its diameter is 56 miles and its massive walls are crowned by a number of superb peaks, one of which rises over 11,000 feet above the interior floor. On the floor itself near the centre are four or five interior mountains, though these are not all easily seen in a small instrument. Tycho, No. 50, is here shown under a very different illumination from that presented on p. 70. "It is," says Webb, "a most perfect specimen of the lunar volcano, roughly figured by Galileo in the earliest telescopic representations. Its diameter is 54 miles, its depth 17,000 feet or nearly three miles, so that the

summit of our Mont Blanc would drop beneath the ring. Its vicinity is thronged with hillocks and small craters, so that for a long distance not the smallest level spot can be found; further off, the craters increase, till the whole surface of the region resembles a colossal honey-comb."* From the region near Tycho radiates that system of light-rays



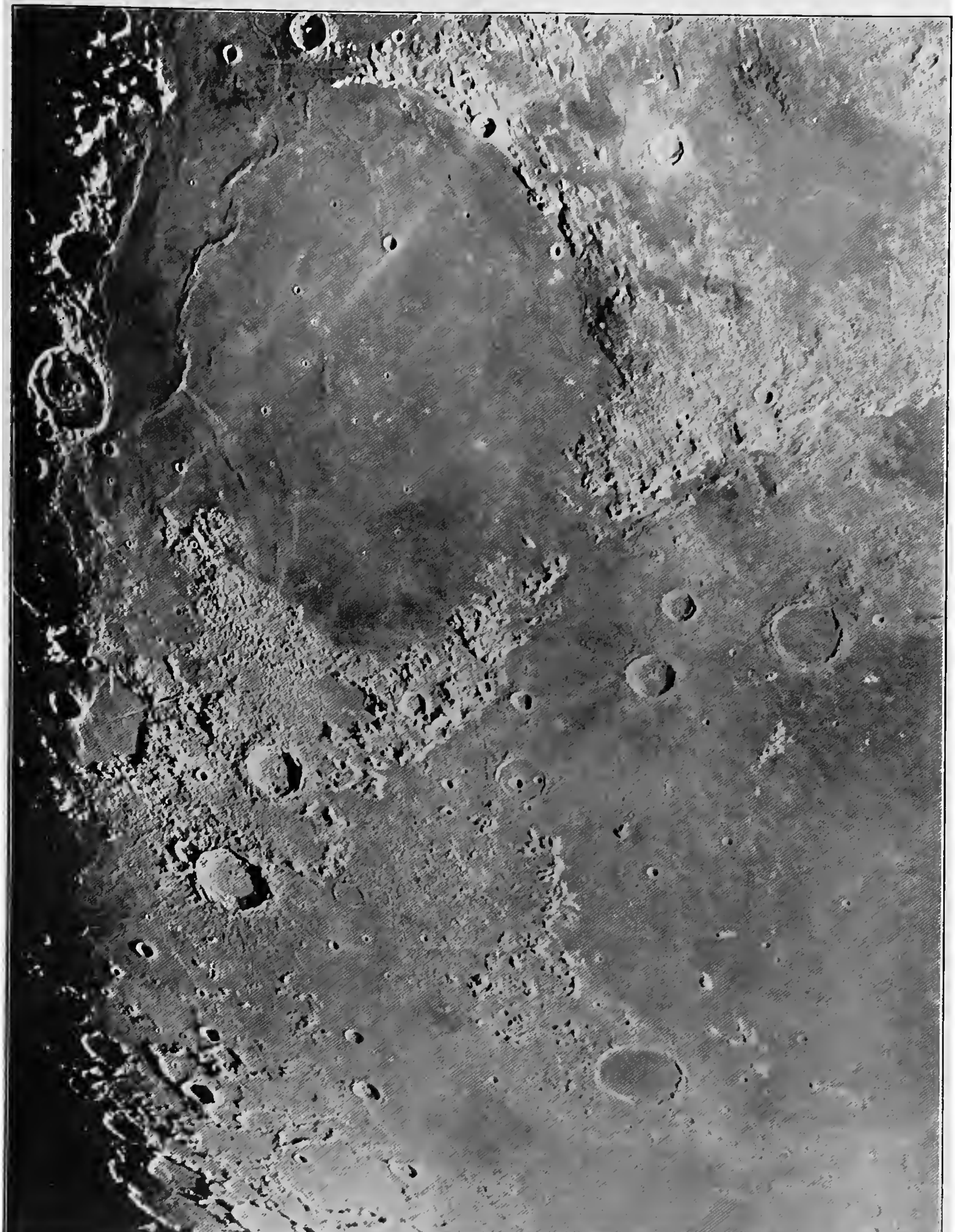
OCCULTATION OF A STAR BY THE MOON

*Aldebaran, at reader's left, just before being occulted or eclipsed by dark limb of Moon; at centre, emerging; at right, shortly after emergence. Photograph from the Yerkes Observatory. For greater clearness, the star's image has been slightly enlarged in engraving*

or light-streaks which seems to dominate the scene at the time of full-moon; see p. 71. Similar systems, though smaller, seem to come from both Copernicus and Kepler under certain phases of illumination, as well as from a number of other points, but the radiations from the vicinity of Tycho are the most pronounced in character and the longest in range. No one has solved the problem of their nature or origin. The recent theory of Fauth that the moon while without water or air is encased in an icy covering, and that the light streaks on its surface are due to glacial conditions subjected to direct illumination, has much to commend it.

"There are," says Noble, in his *Hours With a Three-inch Telescope*, "few more curious, instructive, nay even startling sights in the heavens than the occultation of a fixed star, or more rarely of a planet, by the moon. When this occurs at the dark limb of our satellite, its suddenness is such as not infrequently to extort an exclamation from the observer who witnesses it for the first time. . . . In describing her monthly path over the celestial vault, it is quite obvious that the moon must pass between us and such stars as lie in her course; the stars being—for our present purpose—at an infinite distance, while she is only some 239,000 miles from us. . . . Travelling thus, as I have said, from west to east, her eastern limb is, of course, the leading one, or that which covers, hides, or occults objects lying in her path. From new moon to full moon this limb is unilluminated, and the effect of the extremely sudden extinction of a star when the dark limb hides it is, as I began by saying, of an absolutely startling character. 'In a moment, in the twinkling of an eye,' the star which shone as a brilliant point in the sky is blotted out; and its place seemingly knows it no more, until it reappears from behind the opposite or illuminated edge of the

* *Celestial Objects for Common Telescopes;* by the Rev. T. W. Webb, M.A., F.R.A.S., V Ed., I, p. 121. See also *The Moon*, by Thomas Gwyn Elger, F.R.A.S.; and *The Moon in Modern Astronomy*, by Philip Fauth, with Introd. by J. Ellard Gore, F.R.A.S. To the first two authors, whose volumes are more fully noticed on p. 145, the author is especially indebted.



**THE MOON; REGION OF SEA OF SERENITY AND SEA OF SHOWERS**

*From enlarged photograph taken with the 40-inch Telescope, Yerkes Observatory; see Objects, E, F, 78, 79, 80; 20, 21; 22, 23, 24, 25, etc., in Key-Maps, pp. 76, 74*

moon. After full moon, of course, the eastern limb is illuminated, so that the disappearance takes place at the bright edge, and the star on its reappearance starts instantaneously from behind the dark limb." The more interesting occultations are fully predicted and enumerated for English readers in *Whitaker's Almanac*, and in the *Companion to the Observatory;* and for the United States in the American *Ephemeris*,—see Note on p. 82. The beginner will naturally be interested only in the occultation of the planets or the brighter stars. Our illustration shows Aldebaran just before being occulted or hidden by the dark edge of the moon's disk,—then at brief intervals after its reappearance on the moon's bright side.

## The Planets

The word planet comes from the Greek word meaning "wanderer," for the planets—unlike the stars proper—have an obvious motion of their own. They belong, like the Earth, to "the family of the Sun," moving round the Sun in orbits that are almost circular in form. They are distinguished from the "fixed" stars not only by their obvious motion but by their relative *nearness* also, see p. 9.

**SATURN, 1900**
*From the Yerkes Observatory*

We read, now and then, that a planet is "in" a certain constellation,—that Jupiter, for example, is in Scorpio or that Saturn is in Taurus. This is, of course, a mere convention of speech, based upon the *apparent* place of the planet among the stars. The "fixed" stars of the constellations are inconceivably far away; but as the planets revolve in their orbits they have the stars as their background; and if—as we view the heavens from the earth—we find Saturn moving in between us and Taurus, with the stars of Taurus as the background of the planet, we say that Saturn is "in" Taurus, for the planet seems to be among its stars.

The planets follow a general track or path, and all follow the *same* apparent path through the stars. No one ever saw a planet near the Great Dipper, or in Orion, or in Hercules or Canis Major. Their path lies in close proximity to a line called the "ecliptic"; and this same course is followed by them all as well as by the Sun and the moon. They keep to this path not rigidly, however, but with slight variations to one side or the other; and this general track is called the Zodiac. The star-groups or constellations which form the fixed background of the Zodiac are therefore called the zodiacal constellations. The ecliptic, which is itself the path of the Sun, will be found clearly indicated on the larger of the two maps at the close of this volume. Each planet is always somewhere in the Zodiac and is said to be "in" the constellation lying at the background of this position. The Zodiac or track of the planets lies through the following constellations:—Aries, the Ram; Taurus, the Bull; Gemini, the Twins; Cancer, the Crab; Leo, the Lion; Virgo, the Virgin; Libra, the Scales or Balances; Scorpius, the Scorpion;

Sagittarius, the Archer; Capricornus, the Sea-Goat; Aquarius, the Water-Bearer; Pisces, the Fishes.* The Zodiac extends 8° on each side of the ecliptic.

The Greeks reckoned seven as the number of the "planets," but they included both the Sun and the moon in the list. We do not, of course, include the Sun and moon, but the number is for us seven also,—for we have added to the list in modern times two planets that the Greeks did not know, Uranus and Neptune. The names of the planets, in the order of their distance outward from the Sun, are here printed, with their conventional symbols:—☿ Mercury; ♀ Venus; ⊕ Earth; ♂ Mars; ♃ Jupiter; ♄ Saturn; ⛢ or ♅ Uranus; ♆ Neptune. The largest planet is Jupiter—with diameter nearly eleven times that of the earth; the smallest is Mercury, its diameter a little over $\frac{1}{3}$ that of the earth. Between Mars and Jupiter are a large number of small planetary bodies called Asteroids, many of them only twenty or thirty miles in diameter. These are probably the disunited elements of a planet of importance,—whether arrested in development, or once perfect and now destroyed, no one can say.

**MARS**

*From the Yerkes Observatory*

On the subject of each of the planets a whole volume might be written. In this book there is space only for a few words to the beginner concerning their observation with the telescope. As they move about among the stars it becomes important, first of all, to be able to identify them. Two aids should be possessed by every amateur observer who wishes to know their positions with accuracy,—these are (1) a good almanac for the current year, and (2) the national *Ephemeris* of the country in which he wishes to observe. See footnote on next page.

The beginner is quite likely, just at first, to confuse the brighter planets with the brighter of the fixed stars. Such errors need not surprise or discourage, for they will soon find correction. One of the best of correctives is a fair knowledge of the constellations. As the stars which keep their places come to be known, it becomes a simpler matter to identify the objects which show obvious changes of position. The planets, like the moon, do not move about at random in the sky, but keep their track through the Zodiac, as stated on the preceding page. In distinguishing them, a telescope will also assist. The stars show an increase of *brightness* in the telescope but no increase in size. The planets, however, show a perceptible disk or surface image. Saturn, moreover, is quickly indicated by its ring, Jupiter by his four larger moons. It is often said that, to the unaided eye, the stars may be distinguished from the planets by their twink'ing. It is true that, as a rule, the light of the planets is

* The beginner need not pause over this footnote concerning the "*signs*" of the Zodiac. These are fixed divisions of the ecliptic, each occupying 30° along the circle. These divisions or spaces or "mansions" of the Sun in its path were once coincident with the constellations whose names they bear, but they are not so any longer, each "sign" (or space of 30°) now corresponding to the constellation preceding it,—the *sign* of Aquarius really applying, approximately, to the region along the ecliptic occupied by the stars of Capricornus; the *sign* of Capricornus applying, approximately, to the region of Sagittarius, etc., and finally the *sign* of Aries falling in Pisces. The conventional symbols of the "signs" are as follows:—Aries ♈; Taurus ♉; Gemini ♊; Cancer ♋; Leo ♌; Virgo ♍; Libra ♎; Scorpio ♏; Sagittarius ♐; Capricornus ♑; Aquarius ♒; Pisces ♓. In almanacs, etc., these symbols apply to the "signs," not to the constellations themselves.

far steadier; but there are times when Venus and even Jupiter will seem to twinkle most amazingly, and there are other times—the atmospheric conditions being good—when the light of the stars will be calm and undisturbed. For "twinkling" is caused primarily by the unsteadiness of the air.

JUPITER, 1910
*Photographed at the Lowell Observatory, Flagstaff, Arizona*

In the Tables here printed, the approximate position of the brighter planets is shown month by month for an extended period. These references are not to the conventional "signs" but to the constellations themselves. Such tables cannot be absolutely accurate, but they will well serve as a rough practical guide; and, if the planet be not precisely within the constellation indicated, it will be found sufficiently near to make its identification possible. No tables for Mercury, Uranus, and Neptune are presented, the first being so near the Sun that the stars of the constellations in which it appears are largely obscured at the time by the Sun's light. Uranus and Neptune, on the other hand, are at such great distances from the Sun (1,781,000,000 and 2,791,000,000 miles respectively) that they are too faint in a small instrument to be interesting telescopic objects. Their positions in R. A. and D. may be found from the national *Ephemeris*,* if desired. Uranus shines as a star of about the 6th magnitude; Neptune as a star of magnitude 8, though each presents a slight disk, and careful watching will indicate its slow motion among the stars.

The planetary Tables here printed may be used as follows in connection with the Time Schedule of the Key-Maps on p. 35. (1) We may wish to know whether or not a particular planet (Venus, Mars, Jupiter, or Saturn) is to be seen in the evening sky on a given date. First, find in these Tables the *constellation* in which at that date the planet is likely to be found. Then from p. 35 find the pages on which the Key-Maps are given for the evening sky on the date in question. If the constellation is not shown in these maps, the planet is not visible in the evening sky. If the constellation appears upon the maps, the planet in question will be found therein. (2) We may wish to know which of these planets are in the sky on a particular evening. First, look for the date—year and month—in these Tables. Note the constella-

* For the United States, the observer should write to "The Superintendent of Documents," Washington, D. C., enclosing $1.00 and asking for the *American Ephemeris and Nautical Almanac* for the year desired. The volume may always be had a year in advance. It will contain much that the beginner will not want but it will also contain the position of the moon and planets by Right Ascension and Declination for each day; the predictions of all occultations by the moon for the year, see p. 78; the eclipses of the year; and the phenomena of the satellites of Jupiter and Saturn. In Canada, the same data are to be found in the Annual of the Canadian branch of the Royal Astronomical Society; in Great Britain in the *Nautical Almanac* as well as in such publications as *Whitaker's Almanac* and the *Companion to the Observatory*. Clear and simple tables showing the hours of rising and setting of the planets, the phases of Venus, and much other useful information may be had, in the United States, in such annual almanacs as those published by the *New York Tribune* and the *Brooklyn Eagle*. The *Tribune Almanac* is published, 25c., at the opening of each year. An even simpler volume, 10c., is the *Old Farmer's Almanack*, published by William Ware & Co., Boston, Mass. For its weather predictions I would not be responsible.

tions in which the planets occur. Then find the evening sky for the date in question by reference to p. 35. For example, if our approximate time be the early evening of March, 1912, we find from the Tables here that Mars is in Taurus, Saturn in Aries, Jupiter in Scorpio, and Venus near the boundary between Capricornus and Aquarius. The Time Schedule of the stars, p. 35, refers us to pp. 43, 45, for the skies of the early evening in March. As Scorpio, Capricornus, and Aquarius are not in the skies shown, we know that Jupiter and Venus are not visible. As Taurus and Aries are shown, well over to the west in our Key-Map of the sky, see p. 45, we know that Saturn and Mars are visible and are there before us. As the field covered by our map is rich in brilliant stars, a little care must be given to *distinguishing* the planets from the "fixed" stars. But from the suggestions given on p. 81, and from the general appearance of the planets as indicated in the following paragraph, this should not prove very difficult. (3) We may see a bright object in the sky, not conforming to the lines of the constellation figures, and may wonder what planet it is. On July 1st, 1913, at 9 o'clock P.M., we may see a bright object toward the southeast, not conforming to the outline of the constellation as shown in the Key-Map designated, p. 35, for that date. It seems too bright for a fixed star and yet we are uncertain as to its identity. Noting from the proper Key-Map that the object is "in" Sagittarius, we search here in our planetary Tables for the date in question and find that Sagittarius is given, July, 1913, as the place of Jupiter. Jupiter, therefore, is the unknown object.

SATURN, 1910

*Photographed at the Lowell Observatory, Flagstaff, Arizona*

Mars can often be distinguished by its reddish glow; Saturn by its steady yellow light; Jupiter by its great size, and the soft white color of its globe. Venus is also large and brilliantly white, but it can usually be distinguished from Jupiter by its proximity to the Sun. Jupiter may sometimes be seen throughout the night. Venus must usually be seen shortly after sunset or before sunrise; it can never be seen at midnight or at any position which would involve its being at any great distance from the Sun.

## Mercury (☿)

Mercury is even nearer the Sun than Venus; and while at times quite bright, it is so constantly lost for us in the excessive light that the mere seeing of it is, for the amateur observer, a real achievement. Copernicus is said to have died without ever beholding it. But if the observer will note his current almanac for the times of its "greatest elongation" it may be seen at such times near "the place of the Sun" low down toward the horizon, just before sunrise or just after sunset. Mercury shines about as brightly as a first magnitude star. An opera-glass or field-glass is often very useful in the search for it. The

## The Place of Venus, Month by Month, to 1931

The abbreviations in this Table are:—Taur = Taurus; Gem = Gemini, including Cancer; Leo V = near boundary between Leo and Virgo; Scorp L = near boundary between Scorpio and Libra; Sag = Sagittarius; Cap Aq = near boundary between Capricornus and Aquarius. The small initials at upper left corners of squares are, J = Jupiter; M = Mars; S = Saturn. The use of such initial means that the planet thus symbolized is *also* in that constellation in the same month.

| Year | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1911 | Cap | Aquar | Pisc | Taur | Taur | Cancer | Leo | Leo | Leo V | Leo V | Virgo | Virgo |
| 1912 | J Scorp | J Sag | Cap Aq | Pisc | Aries | S Taur | Gem | M Leo | M Virgo | Scorp L | Sag | Cap |
| 1913 | Aquar | Pisc | Aries | Aries | Aries | M Aries | M S Taur | Gem | Cancer | Leo V | Virgo | Scorp |
| 1914 | Sag | J Cap Aq | Pisc | S Taur | S Taur | Gem | Leo | M Virgo | Scorp L | M Scorp L | Scorp L | Scorp L |
| 1915 | M Sag | Sag | Cap Aq | J Pisc | M Aries | M S Taur | M S Taur | Leo | Leo V | Virgo | Sag | Sag. |
| 1916 | Cap Aq | J Pisc | S Taur | S Taur | S Taur | S Taur | Taur | S Gem | Leo | Leo V | Virgo | Scorp L |
| 1917 | Sag | M Cap Aq | M Pisc | M Aries | J M Taur | S Gem | Leo | Leo V | Virgo | Sag | Sag | Sag |
| 1918 | Sag | Sag | Cap Aq | Pisc | Aries | J Taur | J Taur | Gem | S Leo | Virgo | Scorp L | M Sag |
| 1919 | M Cap Aq | M Pisc | Aries | Taur | M Taur | S Leo | Leo V | Leo V | Leo V | Leo V | M Leo V | M Virgo |
| 1920 | Sag | Sag | Cap Aq | Pisc | Taur | Taur | Gem | S Leo | Virgo | Scorp L | M Sag | Sag |
| 1921 | M Pisc | Aries | M Aries | M Taur | Aries | M Taur | Taur | Gem | M Leo | M S Leo V | J Virgo | Scorp L |
| 1922 | Sag | Cap Aq | Pisc | Taur | Taur | Gem | Leo | J Virgo | Scorp L | J Scorp L | J Scorp L | J Scorp L |
| 1923 | Sag | Sag | Cap Aq | Pisc | Aries | Taur | Taur | M Leo | M Leo V | S Virgo | J Sag | J Sag |
| 1924 | Cap Aq | Pisc | Taur | Taur | Taur | Taur | Taur | Gem | Leo | Leo V | S Virgo | Scorp L |
| 1925 | J Sag | Cap Aq | Pisc | Aries | M Taur | M Gem | Leo | Leo V | S Virgo | J Sag | J Sag | J Sag |
| 1926 | Sag | M Sag | J Cap Aq | Pisc | Aries | Taur | Taur | Gem | Leo | Virgo | S Scorp L | Sag |
| 1927 | J Cap Aq | J Pisc | Aries | M Taur | Taur | Leo | Leo V | M Leo V | M Leo V | Leo V | Leo V | Virgo |
| 1928 | M S Sag | M S Sag | Cap Aq | Pisc | Taur | Taur | Gem | Leo | Virgo | Scorp L | S Sag | S Sag |
| 1929 | Pisc | J Aries | J Aries | J Taur | Aries | J Taur | J Taur | Gem | Leo | Leo V | Virgo | Scorp L |
| 1930 | M S Sag | M Cap Aq | Pisc | J Taur | J Taur | J Gem | Leo | Virgo | Scorp L | Scorp L | Scorp L | Scorp L |

*Facts about Venus :*— The diameter of Venus is 7700 miles; the Earth's 7918; the two planets being almost the same size. Venus is 67,200,000 miles distant from the Sun, revolving about the Sun in 224.7 days,—this being the *year* of Venus. The period of the rotation of Venus on its axis is now thought to be the same as the period of its year,—though this is not altogether certain. The planet moves in its orbit at a velocity of 22 miles a second and for every 100 units of sunlight that fall on Venus 76 are reflected back into space. At greatest brilliance Venus has 12 times the brightness of Sirius; and has 60 times the brightness of Arcturus.

planet is best seen in the *morning* at such western elongations as occur in September and October; it is best seen in the *evening* at such eastern elongations as occur in March and April. For the exposition of such terms the reader may refer to any text-book on Astronomy; see p. 144; but notes and dates of the elongations will be found in any ordinary current almanac. As a telescopic object, Mercury shows almost no detail in a small instrument, but it is always of interest to watch for its "phases." It often assumes—as does Venus—the appearance of a brilliant crescent moon.

These briefly stated facts about Mercury may be of interest:—The diameter is 3030 miles, that of our Earth being 7918 miles. The mean distance of Mercury from the Sun is 36,000,000 miles, but the eccentricity of the orbit is so great that the distance varies between 28,500,000 and 43,500,000 miles. It revolves round the Sun once in about 88 days (this is, therefore, the year of Mercury). The planet moves in its orbit at a velocity of from 23 to 36 miles a second, always turning the same side toward the Sun. For every 100 units of sunlight that fall upon its surface, 14 units are reflected back into space. For these and other data concerning the planets I wish to express my special obligations to the *Astronomie* (IV German Edition), of Newcomb-Engelmann; *The Family of the Sun*, by Holden; *A Manual of Astronomy*, by Young. These are noted more specifically in the List of Books, at the close of this volume.

## Venus (♀)

Venus is so brilliant an object to the eye that the beginner is tempted to expect much from it as a telescopic object. These expectations, however, are never quite fulfilled: the planet is so very brilliant and presents so little detail that it is impossible for the telescope, even though it be a large and perfect instrument, to present a clearly defined image of its sphere. It varies much in apparent size and form, as is well indicated in our small illustration, Fig. 12. It is extremely beautiful, even in a good field-glass, when it puts on the crescent phase. This it does for some weeks before and after "inferior conjunction." For the dates of such conjunctions, see any current almanac. Within this period Venus is at its greatest brilliancy, often being visible by daylight and casting a distinct shadow of its own. Just *at* inferior conjunction, and for a few days before and after, the planet is hidden within the light of the Sun. When midway between greatest elongation and inferior conjunction, its apparent diameter is so great that in the telescope, even with a magnifying power of 45, it assumes the size of the four-day moon, as viewed by the unaided eyes. Venus will not be a satisfactory object for observation during 1912. But she will be "at her best" as follows:— Before *sunrise*, November, 1911; June, 1913; January, 1915; September, 1916; April, 1918; November, 1919; July, 1921; February, 1923, etc. And after *sunset*, February, 1913; September, 1914; April, 1916; November, 1917; July, 1919; February, 1921; September, 1922; April, 1924, etc.

*Fig. 12. Venus*
*Changes in Apparent Size and Form of Planet*

## Mars (♂)

As Mars is farther from the Sun than our Earth, it can never exhibit a crescent phase, as do Mercury and Venus. But, while its orbit is almost circular, its apparent movements are so peculiar, when viewed in relation to the stars through which it moves, that the beginner will find it interesting to follow and plot its course. Make a diagram of the stars,

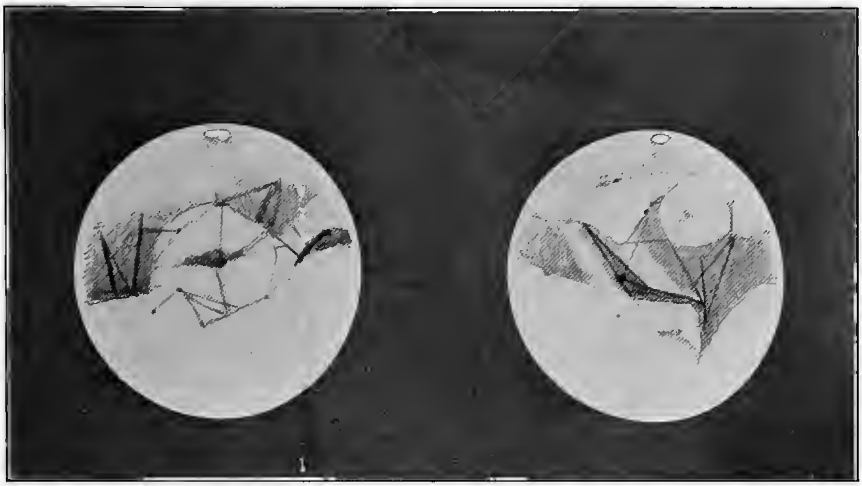
## The Place of Mars, Month by Month, to 1931

The abbreviations in this Table are:—Taur = Taurus; Gem = Gemini, including Cancer; Leo V = near boundary between Leo and Virgo; Scorp L = near boundary between Scorpio and Libra; Sag = Sagittarius; Cap Aq = near boundary between Capricornus and Aquarius. The small initials at upper left corners of squares are, J = Jupiter; S = Saturn; V = Venus. The use of such initial means that the planet thus symbolized is *also* in that constellation in the same month.

| Year | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1911 | Scorp | Sag | Cap | Cap Aq | Aquar | Pisc | S Aries | S Aries | Taur | Taur | Taur | Taur |
| 1912 | Taur | Taur | Taur | Gem | Gem | Cancer | Leo | V Leo V | V Virgo | Virgo | Libra | Scorp L |
| 1913 | J Sag | J Sag | Cap Aq | Aquar | Pisc | V Aries | S V Taur | S Taur | Gem | Gem | Gem | Gem |
| 1914 | Gem | Gem | Gem | Gem | Leo | Leo | Leo V | V Virgo | Virgo | V Scorp L | Sag | Sag |
| 1915 | V Sag | Cap Aq | J Pisc | Aries | V Aries | S V Taur | S V Taur | Gem | Gem | Leo | Leo | Leo V |
| 1916 | Leo V | Leo | Leo | Leo | Leo | Leo V | Leo V | Virgo | Scorp L | Scorp L | Sag | Sag |
| 1917 | Cap Aq | V Cap Aq | V Pisc | V Aries | J V Taur | J Taur | J Taur | S Gem | Leo | Leo | Leo V | Leo V |
| 1918 | Virgo | Virgo | Leo V | Leo V | Leo V | Leo V | Virgo | Virgo | Scorp L | Sag | Sag | V Sag |
| 1919 | V Cap Aq | V Pisc | Pisc | Aries | V Taur | Taur | Taur | Gem | J S Leo | J S Leo | V Leo V | V Virgo |
| 1920 | Virgo | Virgo | Scorp L | Virgo | Virgo | Virgo | Virgo | Scorp L | Scorp L | Sag | V Sag | Cap Aq |
| 1921 | V Pisc | Pisc | V Aries | V Taur | Taur | V Taur | Gem | Leo | V Leo | S V Leo V | S Leo V | J Virgo |
| 1922 | Scorp L | Scorp L | Sag | Sag | Sag | Sag | Sag | Sag | Sag | Sag | Cap Aq | Cap Aq |
| 1923 | Pisc | Aries | Aries | Taur | Taur | Gem | Gem | V Leo | V Leo V | Leo V | S Virgo | S Virgo |
| 1924 | Scorp L | J Sag | J Sag | J Sag | Cap Aq | Cap Aq | Cap Aq | Cap Aq | Cap Aq | Cap Aq | Cap Aq | Pisc |
| 1925 | Pisc | Aries | Taur | Taur | V Taur | V Gem | Gem | Leo | Leo V | Leo V | Virgo | S Scorp L |
| 1926 | S Scorp L | V Sag | Sag | J Cap Aq | J Cap Aq | Pisc | Aries | Aries | Aries | Aries | Aries | Aries |
| 1927 | Aries | Taur | Taur | V Taur | Gem | Gem | Leo | V Leo V | V Leo V | Virgo | S Scorp L | Scorp L |
| 1928 | S V Sag | S V Sag | S Sag | Cap Aq | Pisc | J Aries | J Aries | Taur | Taur | Taur | Taur | Taur |
| 1929 | Taur | Taur | Taur | Gem | Gem | Leo | Leo V | Leo V | Virgo | Virgo | Scorp L | S Sag |
| 1930 | S V Sag | V Sag | Cap Aq | Pisc | Aries | Taur | Taur | Taur | J Gem | J Gem | Leo | Leo |

*Facts about Mars :* — The diameter of Mars is 4,230 miles. The planet's bulk (size) is $\frac{3}{20}$ that of the Earth. Mars turns on its axis in 24 hours, 37 minutes, 22.67 seconds,—this being the *day* of Mars. The planet revolves about the Sun—at a mean distance of 141,500,000 miles—in 686.9 days,— this being the *year* of Mars. The velocity of its motion in its orbit is 15 miles per second. For every 100 units of sunlight that fall on its surface 22 units are reflected back into space. Mars, the planet of War, has two moons, Deimos and Phobos (Fear and Flight). These are so small, however, that they may be seen only by the trained eye through a very large telescope under perfect atmospheric conditions. Their diameters are only about 35 and 10 miles respectively; some observations give only 7 and 5. The inner satellite, Phobos, has a period of only 7 hours, 39 minutes, less than $\frac{1}{3}$ of the planet's day. As viewed from the planet's surface, it rises in the west and sets in the east, making about 3 complete revolutions to the day. If there be inhabitants on Mars, Phobos must serve as a very fair time-piece.

and then from week to week draw a line through them corresponding to the movement of the planet. While some of the more conspicuous markings of the surface are visible in a small telescope the so-called "canals" cannot be seen except in large instruments under favorable conditions. Mars is nevertheless a beautiful telescopic object even for the



MARS, 1909

*Drawing by Dr. Percival Lowell, Flagstaff, Arizona*

beginner,—its clearly defined image and its ruddy light giving a peculiar fascination to such faint details as do appear. Among these are the "hour-glass" marking, so named from its peculiar shape, and the cap of polar snow—though the question as to whether its composition is really that of frozen water is not decided. No object in our night skies, except the moon and one of the small asteroids, comes so near the Earth as does Mars at the time of a favorable "opposition." The planet then shows in a telescope, with a power of 75, a disk as large as that presented by the moon to the unaided eye. At such times its magnitude on a stellar scale is —2.8, the planet then having three times the brightness of Sirius.

Problems as to the habitability of Mars lie wholly outside the limits of this volume. I may say, however, that the question as to "life in other worlds" is not dependent upon the solution of the problems which arise from the planet Mars. We know that all the millions of the fixed stars are suns, many of them greater than our own. We cannot *prove* that these are accompanied by planets—as is our Sun—for no instrument we could devise could ever reveal their presence—the suns themselves being at such great distances from us. But most astronomers are agreed that the existence of such planetary systems is altogether probable.

Nor can we *prove* that on any one of these planets there certainly exists what we call "life." We can only remember that life upon our own planet has persisted and developed under conditions of great difficulty; and that *persistent* phenomena are not likely to be isolated factors in the universe. We find no isolated laws—gravitation is apparently as active at the very verge of "the darkness beyond the stars" as it is upon our Earth. The principles of mechanical action and reaction hold there as here. The spectroscope no sooner reveals "new" elements in the chemistry of the Sun and in the nebulæ of the sky, than we begin to discover the same elements in the composition of our own minerals. Astronomy has revealed the vastness of the universe,—but it is now revealing the *unity* of the universe with evidence as clear in its significance and as cumulative in its force.

## The Place of Jupiter, Month by Month, to 1931

The abbreviations in this Table are:—Taur = Taurus; Gem = Gemini, including Cancer; Leo V = near boundary between Leo and Virgo; Scorp L = near boundary between Scorpio and Libra; Sag = Sagittarius; Cap Aq = near boundary between Capricornus and Aquarius. The small initials at upper left corners of squares are, M = Mars; S = Saturn; V = Venus. The use of such initial means that the planet thus symbolized is *also* in that constellation in the same month.

| Year | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1911 | Libra | Libra | Libra | Libra | Libra | Virgo | Virgo | Libra | Libra | Libra | Libra | Scorp |
| 1912 | V Scorp | Scorp | Scorp | Scorp | Scorp | Scorp | Scorp | Scorp | Scorp | Scorp | Scorp | Sag |
| 1913 | M Sag | M Sag | Sag | Sag | Sag | Sag | Sag | Sag | Sag | Sag | Sag | Sag |
| 1914 | Cap Aq | V Cap Aq | Cap Aq | Cap Aq | Cap Aq | Cap Aq | Cap Aq | Cap Aq | Cap Aq | Cap Aq | Cap Aq | Cap Aq |
| 1915 | Cap Aq | Pisc | M Pisc | V Pisc | Pisc | Pisc | Pisc | Pisc | Pisc | Pisc | Pisc | Pisc |
| 1916 | Pisc | V Pisc | Aries | Aries | Aries | Aries | Aries | Aries | Aries | Aries | Aries | Aries |
| 1917 | Aries | Aries | Aries | Taur | V M Taur | M Taur | M Taur | Taur | Taur | Taur | Taur | Taur |
| 1918 | Taur | Taur | Taur | Taur | Taur | V Taur | V Taur | Taur | Taur | Taur | Taur | Taur |
| 1919 | Gem | Gem | Gem | Gem | Gem | Gem | S Leo | S Leo | S M Leo | S M Leo | S Leo | S Leo |
| 1920 | S Leo | S Leo | S Leo | S Leo | S Leo | S Leo | S Leo | Leo V | S Leo V | S Leo V | S Leo V | S Leo V |
| 1921 | S Leo V | S Leo V | S Leo V | S Leo V | S Leo V | S Leo V | S Leo V | S Leo V | Virgo | Virgo | V Virgo | M Virgo |
| 1922 | Virgo | Virgo | Virgo | Virgo | Virgo | Virgo | Virgo | V Virgo | Virgo | V Scorp L | V Scorp L | V Scorp L |
| 1923 | Scorp L | Scorp L | Scorp L | Scorp L | Scorp L | Scorp L | Scorp L | Scorp L | Scorp L | Scorp L | V Sag | V Sag |
| 1924 | Sag | M Sag | M Sag | M Sag | Sag | Sag | Sag | Sag | Sag | Sag | Sag | Sag |
| 1925 | V Sag | Sag | Sag | Sag | Sag | Sag | Sag | Sag | Sag | V Sag | V Sag | V Sag |
| 1926 | Cap Aq | Cap Aq | V Cap Aq | M Cap Aq | M Cap Aq | Cap Aq | Cap Aq | Cap Aq | Cap Aq | Cap Aq | Cap Aq | Cap Aq |
| 1927 | V Cap Aq | V Pisc | Pisc | Pis | Pisc | Pisc | Pisc | Pisc | Pisc | Pisc | Pisc | Pisc |
| 1928 | Pisc | Pisc | Aries | Aries | Aries | M Aries | M Aries | Aries | Aries | Aries | Aries | Aries |
| 1929 | Aries | V Aries | V Aries | V Taur | Taur | V Taur | V Taur | Taur | Taur | Taur | Taur | Taur |
| 1930 | Taur | Taur | Taur | V Taur | V Taur | V Gem | Gem | Gem | M Gem | M Gem | Gem | Gem |

*Facts about Jupiter:*—In addition to the facts already cited, it is well to remember that although so great in size, Jupiter turns on its axis in only 9 hours and 55 minutes (the *day* of Jupiter). This motion being so rapid and the density of the planet being so low, there has taken place an obvious flattening at the poles. Jupiter goes round the Sun once in 11.86 years (the *year* of Jupiter) at a mean distance of 483,300,000 miles; the velocity of the orbital motion being 8 miles per second. For every 100 units of sunlight that fall on the planet's surface, it is estimated that 62 units are reflected back into space. The planet at its brightest has about twice the brilliancy of Sirius. Jupiter has eight moons in all—four being too small for observation with the average telescope.

That such a phenomenon as "life," persistent here through such varied and difficult conditions, through so long a period and under so many forms, is a unique and isolated fact becomes increasingly improbable. The beginner may be warned, however, that such suggestions are speculative, and that they lie largely outside the domain of astronomy proper.

## Jupiter (♃)

Jupiter is truly called the giant planet, for it is not only 1,309 times the bulk (size) of the Earth, but larger than all the other planets combined. Its weight, however, is only about $1\frac{1}{3}$ times as great as the same quantity of water, so that its density is much less than that of our Earth or our moon. Its chief fascination in the telescope lies in the movements of its four larger satellites. These can be seen even in a 10x field-glass steadily held, and their observation in a small telescope may prove a source of great interest and pleasure. They are known, in the order of their distance from the planet, as I, II, III, IV,—their names being Io, Europa, Ganymede and Callisto. All are larger than our own moon, Ganymede—the largest and brightest—having a diameter of 3,600 miles.

*Fig. 13. Jupiter*
*With his Four Larger Moons*

They are not always placed as in our little picture, Fig. 13. Sometimes all four are to be observed on one side of the planet; sometimes we may see three on one side and one on the other. At times, one will pass, in its orbit, *behind* the planet and be lost to view; or it will be lost to view as it passes in *front* of Jupiter, being obscured in the planet's greater light and casting a tiny shadow on the planet's disk. These movements take place with such rapidity that the apparent changes of position may often be detected in a couple of hours. It is worth while, therefore, to take two observations of Jupiter on the same evening, if possible, one at an early hour and one later.

The movements of these moons of Jupiter, their positions, eclipses, etc., are all predicted and set forth in the national *Ephemeris* to which reference has been made in the footnote on p. 82. A small telescope will also show the flattening of the planet's globe at the poles and the two greater cloud belts. The markings as shown in Fig. 13 are too sharply defined. As the size of the telescope is increased, more and more detail, however, can be seen, and sometimes a large marking, called "the great red spot," can be discerned. As Fowler suggests, any detail that can be noted must be important in size, for the diameter of the planet is about 86,500 miles. Drawings of the disk of the planet, if carefully made, are often of future interest and value.

## Saturn (♄)

This is one of the most beautiful of telescopic objects. The ring formation revolving about the planet—a thing unique, so far as our knowledge of the universe extends—may be seen in any good telescope that will yield a power of 20 diameters. The beginner, however, will usually require an instrument a little larger, with an object-glass of 2 or $2\frac{1}{4}$ inches in aperture, in order to see this formation with any real satisfaction. Every increase in the size and quality of the telescope will add new clearness and beauty of detail; for Saturn will well bear all the magnifying power consistent with the capacity of the eye and the instrument.

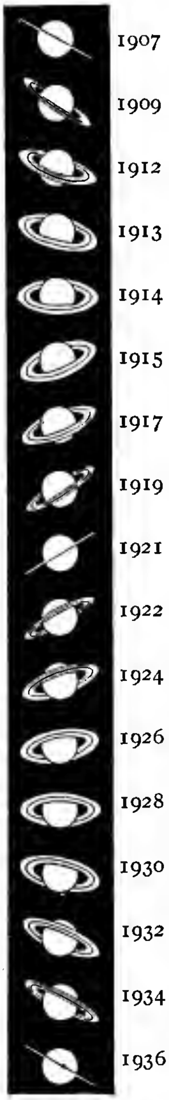
## The Place of Saturn, Month by Month, to 1931

The abbreviations in this Table are:—Taur = Taurus; Gem = Gemini, including Cancer; Leo V = near boundary between Leo and Virgo; Scorp L = near boundary between Scorpio and Libra; Sag = Sagittarius; Cap Aq = near boundary between Capricornus and Aquarius. The small initials at upper left corners of squares are, J = Jupiter; M = Mars; V = Venus. The use of such initial means that the planet thus symbolized is *also* in that constellation in the same month.

| Year | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1911 | Aries | Aries | Aries | Aries | Aries | Aries | M Aries | M Aries | Aries | Aries | Aries | Aries |
| 1912 | Aries | Aries | Aries | Aries | Taur | V Taur | Taur | Taur | Taur | Taur | Taur | Taur |
| 1913 | Taur | Taur | Taur | Taur | Taur | Taur | M V Taur | M Taur | M Taur | Taur | Taur | Taur |
| 1914 | Taur | Taur | Taur | V Taur | V Taur | Taur | Taur | Taur | Taur | Taur | Taur | Taur |
| 1915 | Taur | Taur | Taur | Taur | Taur | V M Taur | V M Taur | Taur | Taur | Taur | Taur | Taur |
| 1916 | Taur | Taur | V Taur | V Taur | V Taur | V Taur | Gem | V Gem | Gem | Gem | Gem | Gem |
| 1917 | Gem | Gem | Gem | Gem | Gem | V Gem | Gem | M Gem | Gem | Gem | Gem | Gem |
| 1918 | Gem | Gem | Gem | Gem | Gem | Gem | Gem | Leo | V Leo | Leo | Leo | Leo |
| 1919 | Leo | Leo | Leo | Leo | Leo | V Leo | J Leo | J Leo | J M Leo | J M Leo | J Leo | J Leo |
| 1920 | J Leo | J Leo | J Leo | J Leo | J Leo | J Leo | J Leo | V Leo | J Leo V | J Leo V | J Leo V | J Leo V |
| 1921 | J Leo V | J Leo V | J Leo V | J Leo V | J Leo V | J Leo V | J Leo V | J Leo V | Leo V | M V Leo V | M Leo V | Leo V |
| 1922 | Leo V | Leo V | Leo V | Leo V | Leo V | Leo V | Leo V | Leo V | Leo V | Virgo | Virgo | Virgo |
| 1923 | Virgo | Virgo | Virgo | Virgo | Virgo | Virgo | Virgo | Virgo | Virgo | V Virgo | M Virgo | M Virgo |
| 1924 | Virgo | Virgo | Virgo | Virgo | Virgo | Virgo | Virgo | Virgo | Virgo | Virgo | V Virgo | Virgo |
| 1925 | Virgo | Virgo | Virgo | Virgo | Virgo | Virgo | Virgo | Virgo | V Virgo | Virgo | Scorp L | M Scorp L |
| 1926 | M Scorp L | Scorp L | Scorp L | Scorp L | Scorp L | Scorp L | Scorp L | Scorp L | Scorp L | Scorp L | V Scorp L | Scorp L |
| 1927 | Scorp L | Scorp L | Scorp L | Scorp L | Scorp L | Scorp L | Scorp L | Scorp L | Scorp L | Scorp L | M Scorp L | Sag |
| 1928 | V M Sag | V M Sag | M Sag | Sag | Sag | Sag | Sag | Sag | Sag | Sag | V Sag | V Sag |
| 1929 | Sag | Sag | Sag | Sag | Sag | Sag | Sag | Sag | Sag | Sag | Sag | M Sag |
| 1930 | V M Sag | Sag | Sag | Sag | Sag | Sag | Sag | Sag | Sag | Sag | Sag | Sag |

*Facts about Saturn:*—In addition to what has been said, it may be interesting to note that the diameter of Saturn's sphere is about 73,000 miles,—about nine times that of the Earth. Saturn is distant from the Sun 886,000,000 miles, or about 9½ times as far from the Sun as is the Earth. It takes 29.46 of our years for Saturn to go completely round the Sun,—this period representing, therefore, the *year* of Saturn. The planet moves in its orbit at a velocity of 6 miles a second; and for every 100 units of sunlight falling on it, about 72 units are reflected back into space. Saturn is the most remote from the Sun of the planets known to the ancients. Galileo partly discovered the "rings," but his largest instrument was too imperfect to exhibit their real structure. They soon turned "edge on," as in 1907, and he died without solving the mystery. That the appearances which baffled Galileo were *rings* was discovered by Huygens, the Dutch astronomer, in 1655.

The ring formation is seen, with higher powers, to be divided, and to present the following conditions. The observer first notes—even in a telescope of 3¼ or 3½ inches—that the encircling mass is divided into two bright rings, called by astronomers, A and B. They are separated by a dark line called "Cassini's" or "Ball's" Division. A is the outer ring, its exterior diameter being 173,000 miles. Its light is of a hue more golden than that of the second ring, B. The light of B is brighter and more silvery. In A there is a further line called Encke's Division; and at the inner edge of B there is a darker ring, C,—sometimes called the "gauze" ring because of its shadow-like texture. But this phenomenon, as well as Encke's Division, can be seen only in the largest telescopes. The rings of Saturn are swarms of tiny satellites, or "moonlets," each revolving in its own orbit. The rings are really circular—their apparently elliptical form being due to the angle at which we must view them from the Earth. If we were directly above Saturn, or directly below, we should be able to see that they are circles.



*Saturn*
*Fig. 14, Phases from 1907 to 1936*


SATURN
*From Photograph by Dr. Percival Lowell, Lowell Observatory, Flagstaff, Arizona*

The constant changing of the relative positions of Saturn and the Earth, as the two planets move in their orbits round the Sun, naturally changes the direction from which we see the rings. Sometimes our line of sight is such that we view the rings "edge on" as in 1907. They are then almost invisible. In our illustration, Fig. 14, which I here use by courtesy from Prof. David Todd's admirable *New Astronomy*, the "phases" of Saturn are shown through an extended period, till 1936. They are so beautiful in a small telescope under even moderate powers that they form an exhaustless source of charm and interest.

Saturn is accompanied by ten moons. Their names are Japetus, Hyperion, Titan, Rhea, Dione, Tethys, Enceladus, Mimas, Phoebe, and Themis. The whole system is very great in its extent, Phoebe being at a distance from the planet of 7,860,000 miles. Even a 2-inch telescope will usually show Titan, the largest. A 3-inch telescope will sometimes show Japetus, next brightest, and—on rare occasions—even a third, Rhea. A 4-inch will usually add two others. The apparent motion of the satellites of Saturn is so much slower than in the case of the moons of Jupiter, and their relation to the planet is so much less obvious, that their interest for the observer is not so great. The bulk (size) of the globe is more than 750 times that of the Earth, though it possesses a density less than that of water. As this huge mass revolves on its axis

**HALLEY'S COMET, MAY 5, 1910**

*From a photograph taken at the Yerkes Observatory*

with great rapidity, completing its revolution in 10 hours, 14 minutes (the *day* of Saturn), the great ball is "bulged out" or broadened at the equator and flattened at the poles. This oblateness of the sphere is even more marked than in the case of Jupiter. A small telescope will show it.

## Comets and Meteors

There is no weighty reason why any amateur astronomer should not be the discoverer of a comet. The requisites are a telescope of low power, large field, and generous illumination; a good store of pertinacity and patience; and a fair knowledge of the constellations—in order that the observer, by reference to the neighboring stars, may be enabled to decide as to the fact of motion in a suspected object. If, after several hours, no motion—in reference to surrounding stars—be noted, the probabilities are that the object is not a comet but a nebula. For almost all comets, especially on our first view of them, look much like nebulæ, having the appearance of small patches of mist. These may never grow much brighter, may never show nucleus or tail, and may bring not much of fame or pride to the discoverer. But the essential characteristic of a comet may have been found. This is the *coma*, the misty cloud of faintly luminous material of which we have been speaking. The essential thing is not a "tail" nor even the nucleus (the bright core, or point almost starlike in its brilliance, at the centre of the coma) but the coma itself.

As we look at the illustrations of a comet we naturally think of it as rushing through space with its tail streaming out behind it just as a flame of fire streams backward from a hurtling torch. The tail of the comet, however, sometimes goes *before* it. In fact, the tail (if there *be* a tail) always extends from the comet in the direction opposite to the Sun,—so that as a comet approaches the Sun the head precedes the tail, but as it leaves the region of the Sun the tail precedes the head. Through causes which no one has yet fully explained, the Sun, while powerfully attracting the comet as a whole, seems to exert a repulsive force upon the infinitely refined material of which the tail is formed. The head or coma of a normal comet is frequently as much as 100,000 miles in diameter. Many are far larger. The tail ranges in length from 10,000,000 to 100,000,000 miles; the diameter of the nucleus, or bright point within the head, is from 100 to 5000 miles.

Astronomers differ as to the nature of the stuff or matter of which the nucleus is composed. Some have supposed this matter to be made up of swarms of meteors,—or extremely small particles, widely separated, glowing with an incandescent heat resulting from collisions with one another, or luminous from some form of electrical action. No positive knowledge is yet at hand. We do know, however, that the stuff or matter of a comet is, on the whole, of almost inconceivable rarity or tenuity, so thin and impalpable that probably no harm to us could result from any possible collision with such a body.

Comets which have closed orbits return again, and their return may in many cases be predicted. Among these are Encke's, with a period of 3¼ years; Swift's, with a period of 5½ years; Tuttle's, with a period of 13¾ years; and Halley's, with a period of 76 years. The last named is the most famous because it was the first to have its return predicted and the first to indicate the feasibility of such calculations. Many of the noblest comets of history have not been again identified, either because their orbits are not closed—bearing them forever beyond our solar system—or because, though closed, their orbits are so vast as to permit their return only after hundreds or even thousands of years. Our illustrations

are chiefly from photographs of Halley's Comet taken at its recent return. It has returned periodically for many centuries, sharing intimately in some of the critical occasions of history, as in the Norman Conquest, A.D. 1066. The opening scenes of Tennyson's drama, *Harold*, contain some striking and significant references to the strange visitor. For while

COMET MOREHOUSE, 1908

*Photographs from the Yerkes Observatory; taken three hours apart*

we now know that comets are altogether harmless to our Earth, they were often supposed by the ancients to be the forerunners of calamity if not the symbols of divine displeasure. In noting our photographs of the comets, see p. 29 as well as pp. 92, 95, 137, the reader should give no regard to the light-streaks that appear on the photographic plate. These are traces of the stars. The camera must be adjusted to follow the comet. If the exposure must be a long one, as is usually the case, the apparent movement of stars is not likely to be at either the same angle or at the same velocity as that of the comet, and the traces of the star-images must appear upon the plate. Several types of comets are shown. That of Giacobini, p. 29, was remarkable for the large relative size and impressive form of its head; that of Morehouse, above, for the relative smallness of the head and the peculiar form and striking changes of the tail.

Of meteors there is little to be said in a volume such as this, because they are of small telescopic interest. They are not, of course, real shooting "stars," for they are relatively very small and they live and perish within our solar system. They "rain a ceaseless rain" upon the Earth. Nor do they fall at random out of space, as was once thought. They revolve, apparently in swarms, in orbits about the Sun,—some speeding in the same direction as the planets, some with motions that are retrograde, and some in orbits that cross our own. So rapidly do they move that they enter our atmosphere with a velocity which by the force of its impact with the air raises them to a heat of inconceivable intensity. The smaller bodies shine for a moment or two and are consumed; the larger fall, and when

**HEAD OF HALLEY'S COMET, MAY 8, 1910**

*Reduced from Photograph taken at the Mt. Wilson Solar Observatory*

*See also pp. 92 and 137*

picked up are called meteorites and aërolites. From about July 20th to Aug. 16th (maximum of display Aug. 11th) the earth passes through a swarm of meteors which seem to radiate from the direction of the constellation Perseus. They are therefore called "the Perseids." In November, about the 15th, we meet the Leonids, coming from the apparent direction of Leo. The Geminids (Gemini) are seen about December 7th and for some days thereafter. November 24th is the date for the Andromedes; October 19th, for the Orionids; May 6th, for those coming from the region of the star Eta ($\eta$) in Aquarius; July 28th, for those coming from the region of Delta ($\delta$) in Aquarius; April 20th, for those coming from the region of Lyra. In counting them, an opera-glass or a field-glass of low power is sometimes useful, especially in noting those with the lower velocities. The three important points to be noted are the *number* per hour, and the *duration* and *direction* of their flight. In fixing the direction in the observer's memory, a cane or wand instantly held in line with the meteor's flight has often proved a convenience. That meteors are the fragmentary masses of former, or still existent, comets is now the generally accepted theory of their origin. Fuller information as to both classes of objects may be had in the general volumes on astronomy mentioned on p. 144,—especially in those by Sir Norman Lockyer and Miss Agnes M. Clerke. See, also, p. 143 of this volume under the head of "Useful Work for the Amateur."

"On a starred night Prince Lucifer uprose.
Tired of his dark dominion swung the fiend
Above the rolling ball in cloud part screened,
Where sinners hugged their spectre of repose.
Poor prey to his hot fit of pride were those.
And now upon his western wing he leaned,
Now his huge bulk o'er Afric's sands careened,
Now the black planet shadowed Arctic snows.
Soaring through wider zones that pricked his scars
With memory of the old revolt from Awe,
He reached a middle height, and at the stars,
Which are the brain of heaven, he looked, and sank.
Around the ancient track marched, rank on rank,
The army of unalterable law."

George Meredith: *Lucifer in Starlight.*

## VII. Some Instruments of Observation

### The Opera-Glass and Field-Glass

Said a distinguished astronomer, the late R. A. Proctor: "I have often seen with pleasure the surprise with which the performance even of an opera-glass, well steadied, and directed towards certain parts of the heavens, has been witnessed by those who have supposed that nothing but an expensive and colossal telescope could afford any views of interest. But a well-constructed achromatic telescope of two or three inches in aperture will not only supply amusement and instruction; it may be made to do useful work."* Such a statement is even more applicable to-day than when Proctor wrote it. Not only are our small telescopes better in quality, but the modern opera-glass and field-glass are more fully adapted to astronomic uses.

A MODERN OPERA-GLASS

The opera-glass is not, as is sometimes supposed, either a plaything or a toy. It is a serious instrument. While it cannot do the work of a great telescope, it can do some things for which the great telescope is unfitted. We may remember the retort of the squirrel to the mountain, in Emerson's quaint poem: "If I cannot carry forests on my back, neither can you crack a nut!"

The opera-glass, because small in size, may be slipped easily into the pocket; and, because light in weight, may be handled and used for long periods without fatigue. With it one may catch the view of a meteor's trail more quickly than with a heavier instrument. It can be always ready. Because its magnifying power is not high, it is less easily affected than the telescope by fogs and mists; and, for the same reasons, its use is more practicable in travel,—as on shipboard or on a moving train. Moreover, its magnifying power is quite sufficient to be of frequent aid in following a comet, in studying brilliant star-fields like those found in the Pleiades and in Orion; and it is of special value in helping the amateur observer to trace the outlines of the constellations. Even after the telescope has been adopted and is well understood, an opera-glass is often of definite service in examining unfamiliar star-fields—especially upon dull or hazy nights—in order that the larger instrument may be intelligently directed.

As with all optical products these vary in quality. There are opera-glasses and opera-

* *Half Hours with the Telescope*, by R. A. Proctor, M.A., F.R.A.S.; p. 1; Longmans, Green & Co., New York and London, 1868.

glasses. Often the same glass that has been used for years at the theatre is also quite satisfactory for the study of the stars. The best for this purpose are undoubtedly those having large object lenses,—the object lenses are at the end nearest the object viewed; or, in other words, the lenses at the large end of the instrument. The larger these are—other things being equal—the larger will be their light-collecting power. Magnifying power is not so important in such a glass as its power to show a fairly large field brightly and clearly lighted. The beginner should be constantly on guard against the temptation to exaggerate the importance of mere magnifying power.


FIELD-GLASS: PRISM BINOCULAR TYPE

I cannot concur in the opinion sometimes expressed that it is wise, in purchasing an opera-glass, to go to odd and out-of-the-way places to secure one. There are doubtless excellent glasses to be found in some of these shops. But in going to a regular dealer you may not only be reasonably sure your glass is what it is represented to be, but you are dealing with one who will have a permanent interest in its quality and service. Excellent glasses may be had of the regular dealers at very moderate prices, ranging from $4 or $5 to $15 or $20 a pair.

The optical principles represented in the opera-glass involve, however, certain limitations as to power. Some glasses magnify but 2½ diameters, some magnify 3, some 3½ or 4. But the greater the magnifying power the greater in length must be the tubes or cylinders of the instrument. The *ordinary field-glass* is, accordingly, but an opera-glass of greater length; and because the principle of construction is the same as that employed by Galileo in his earliest models of the telescope, such an instrument is said to be of the "Galilean" type. The Galilean field-glass has greater magnifying power than the opera-glass; and, if well made, will present images or pictures of great sharpness and clearness. But in some of these instruments the picture is not well lighted or sharply defined except at the very centre of the field of view; the field of view is small, at best; and the physical weight of glasses of this type is quite large for the magnifying power afforded. When, therefore, a magnifying power of 7 or 8 diameters is attempted the Galilean field-glass usually becomes too large and bulky for comfortable use.

There is, however, one modern improvement much to be commended to the purchaser who can afford it. This is the device for permitting the adjustment of the glass to varying pupillary distances. The eyes are not the same distance apart in all heads, and these "jointed bars" permit the comfortable adaptation of the field-glass to the individual. Where the "jointed bars" cannot be obtained and the frame is therefore rigid, be sure to select your glass so that it is suited to the distance between your own eyes. This can be easily tested by noting whether the two tubes of the glass present a single field of view. The two miniature telescopes of which the field-glass is composed should do good "team-work." They should show one picture. It is well to select the plainest, simplest "finish" as the most desirable, especially for outdoor use; and if the instrument be that of one of the better manufacturers it will more than justify the amount expended in its purchase.

THE PRISM BINOCULAR

By the invention, however, of the prism binocular, another type of field-glass is now available. A new principle has been brought into play. Some sixty years ago a French engineer named Porro discovered that through the introduction of highly polished glass prisms, at the proper intervals within the tubes, the rays of light could be so "doubled back" upon themselves that the optical necessity for the increased length demanded by increased power could be eliminated. High powers could thus be provided for, through tubes that might be actually very short. This ingenious suggestion has now been so broadly adopted that there are many kinds of "prism binoculars," several of the different "makes" representing a high degree of optical refinement. They are naturally more expensive in price than glasses of the Galilean type. The fitting and polishing of the prisms, and the very rigid mechanical construction demanded in the body of the instrument, require workmanship of rare experience and skill. The Galilean field-glass ranges in price at retail from $10 to $20; the better grades of prism binocular range from $40 to $75,—though there are some as low as $25 and some as high as $90. Much depends upon the precise model desired. As in the case of the opera-glass, the best types for astronomical purposes (costing from $40 to $75) are those possessing large object lenses. The large object lenses, as already explained, ensure for the instrument a large light-collecting capacity. This increases the pleasure in its use at night and also gives it a high penetrating power under adverse conditions of light and air.

HIGH POWER, PRISM BINOCULAR, FIELD-GLASS

*On Tripod Support*

Not only are these instruments smaller, in proportion to their magnifying power, than the Galilean glass, but they present a large field of view, well defined, and clearly and evenly lighted to the very edge of the picture. The optical conditions, however, which result in the *relative* reduction of both light and field with the increase in magnifying power are inexorable, and apply here also in spite of the superiority of the prism binocular to the Galilean glass. Because of these conditions it is not wise to select, even in a prism binocular, a power in excess of 6 or 7 or 8 diameters if the instrument is to be given "free-hand" use,—is to be used without some form of artificial support. For we must also bear in mind the fact that just as your field-glass magnifies the objects to which you direct it, it *must* also magnify—and precisely to the same extent—the trembling or unsteadiness of the directing hand. The higher the magnifying power you employ the more difficult you will find it to hold your instrument "steady,"—unless you use some form of artificial support. The various magnifying powers—as 6×, 7×, 8×, 9×—are usually specified upon the frame or body of the glass. The symbol × means "times" and represents the *times* an object is magnified, or the extent to which the apparent diameter of an object is increased. In the same way we say that a glass or telescope has a power of 8 or 15 or 100 diameters. This means that the instrument increases to this extent the apparent diameter of the object.

Where, however, some form of artificial support for the glass can be purchased or devised,

much satisfaction can be found in powers as high as 10, 12, 15, or even 18. Prism binoculars may be had in all these magnifications and if care be taken to select a model having large object lenses, and thus affording abundant light, such a glass has some advantages over the small telescope. Among these advantages we cannot include economy, for they are more expensive than some telescopes, ranging in price from $60 to $90. They do, however, afford the pleasure and comfort of "binocular" as opposed to "monocular" vision; that is to say, we may use *both* eyes naturally and easily in looking through them. A power under 20 diameters, however, will not show the ring formation of Saturn, or many of the double stars. But such a glass, even if it have only a power of 10, will divide a few of the double stars, will show the four larger satellites of Jupiter, the crescent phase of Venus, and beautiful views of the more conspicuous features on the surface of our own moon. Metal holders or clamps may be purchased of almost any optician, either with an accompanying metal support, or to be used in adjusting the glass to any ordinary camera tripod. The large object lenses provided with instruments of this type make them especially useful in looking for comets or in viewing brilliant star-groups such as the Pleiades.

## The Spy-Glass or Draw-Telescope

This familiar glass, the ordinary hand telescope of the mariner and the hunter, affords neither the comfort of "binocular" vision nor the high magnifying power of the regular astronomical instrument, but it is inexpensive and it will often do good work. For views of the wider double stars, for the coarser star-clusters, and for the study of our own moon and of the four larger moons of Jupiter, such telescopes are usually quite adequate. Their eyepieces present an "erected" image—a term we will explain a little later on—and so their objects in the field of view are "right-side-up," as in an opera-glass or a field-glass, but this field of view is small and not well lighted. Unfortunately the eyepieces furnished with them are often of higher magnifying power than the size of the object lens and the construction of the instrument will justify, but the manufacturers are gradually correcting this error. There has been prevalent a natural but thoroughly unintelligent demand on the part of the public for "high" magnifying powers in all of our popular field-glasses and telescopes. Manufacturers long felt that they must yield to this demand, though they knew it to be self-destructive (a magnifying power so high as to compromise the pleasure-giving quality of the telescope is "bad business" commercially as well as astronomically) but happily a change is now at hand.

In using a spy-glass, or hand telescope, remember that to do any sort of satisfactory work it must be steadily held. The metal clamps used for fixing a field-glass to a tripod are just as well adapted to the spy-glass. If these are thought to be too expensive, the amateur who possesses a little skill at wood-working can make his own mounting, at very low cost and with small trouble. A forked staff set in the ground, the telescope resting in the fork, is better than nothing. At the section of the telescope at which the instrument is grasped by the metal clamp or by the fork a piece of soft cloth or chamois-skin should be wrapped about the tube, to prevent its polish from being injured. This piece of soft leather or cloth may be held by a few stitches or by a couple of tight rubber bands.

This type of telescope is usually made in sections or joints, the smaller sliding down into the larger when the instrument is closed. The instrument must, of course, be extended or *drawn* out for use in observation—hence the name "draw-telescope" is often applied to it. A three-draw telescope or a four-draw telescope is one having three or four, as the case may be, of these several sections. The focusing is accomplished by sliding in or out the

section containing the eyepiece. Telescopes of this type will not, of course, give the satisfaction afforded by instruments regularly mounted on tripod stands and provided with one or more regular astronomical eyepieces, but they are inexpensive, easily carried about, and capable—within their range—of giving a great deal of pleasure to the beginner. Their prices range from $5 to $50 according to quality and size.

### The Astronomical Telescope

Portable telescopes mechanically mounted on tripod stands may be had in almost any size from an "aperture" of 1½ inches to 5 inches. The "aperture" (literally = opening, or space through which light passes) of a telescope represents the surface diameter of the object lens, or the "objective." The object lens or objective of the telescope, as already explained, is at the large end; the lens at the small end is called the "ocular" or sometimes—in a general sense—the eyepiece. The *size* of the telescope is usually described in terms of the objective,—a "2-inch" is a telescope with the objective 2 inches in diameter; a "3-inch" is a telescope having an object lens 3 inches in diameter, etc. Telescopes are also classified as to *type* or *kind* as "reflectors" and "refractors." The reflectors are the better for such work as astronomical photography; the refractor is the type found in most general use, especially among amateur observers. Moreover, the greater achievements in observation have been thus far accomplished by instruments of this kind. The famous 36-inch telescope of the Lick Observatory and the 40-inch telescope of the Yerkes Observatory are both refractors. This book deals exclusively with the using of small refractors, inasmuch as this is the type of instrument found in the stock of the average optician and used in practical work by the larger number of observers;—but those possessing reflectors will find the directions and instructions easily adapted to their instruments.

A telescope has but one objective or object lens, but it may have several eyepieces. One eyepiece may be removed to make place for another; the object lens, however, should never be removed, except at long intervals for cleaning: we will speak below, see note 9, p. 111, of the proper cleaning of lenses. If you find a few small "bubbles" in the glass of the objective these need cause you no concern. They are often found in glass of the highest quality, and—unless present in large numbers—they will not affect the optical qualities of any telescope that is in other respects a good one. The telescopes of well-known makers are, as a rule, carefully tested before leaving the factory, for a poor instrument is a poor advertisement. The beginner may usually be sure, therefore, that his telescope is all right. Suggestions for the testing of objectives are found in some volumes, but one who is using a telescope for the first time is seldom able to apply these instructions successfully. They have often caused more anxiety than aid. Upon the other hand, helpful advice may often be had from observers of larger experience. There is a fine *esprit de corps* among amateur astronomers and those who have met and solved their telescope-problems are usually glad to be of service to those who are entering the fellowship.

Yet it is true that the user of a telescope is more or less bored by such enquiries as "How far can you see with it?" One may well retort, "I can see no farther with it than without it!"—for in beholding some of the brighter stars with the unaided eyes we are seeing to the limit of mental comprehension,—a distance which if stated in English miles could not be expressed in twenty million consecutive human lifetimes, if every breath of each were to represent a mile. The value of a telescope cannot be expressed in terms of the linear distance which it can penetrate. Nor can it be well expressed in the terms of mere magnifying power, for the highest magnifying power optically possible to it may

be—because of the conditions of the atmosphere or the limitations of the eye—altogether useless from a practical standpoint. What, then, does a telescope do for us? It does have both a penetrating and a magnifying power, but its chief function is the collecting of light for the eye,—illumination. No amount of magnifying will prove of service to us if the mere enlargement of the size of the image is not coincident with its adequate illumination in the field of view. And in the case of the stellar world, the distance of which is optically and practically at infinity, the illumination of the field of view is the chief function of telescopic aid. I here make no reference to the telescope scientifically mounted as an instrument of *precision* for the measuring of angles, etc. I refer to the telescope in average hands.

The observer in attempting to see and to study the familiar objects of astronomic interest is constantly forced to realize that merely increasing the size of an image may actually prevent his seeing it, for the increase in magnifying power necessarily involves not only the reduction of the size of the field of view but the proportionate shutting out of the light needed for its study. Let us therefore first try to appreciate the telescope's light-collecting power. This is proportionate, as we have seen, to the size of the object glass. The diameter of the eye's pupil is about $\frac{1}{5}$ of an inch; and working with the formula that "the light-gathering powers of the eye and the telescope are to each other as the squares of their apertures" we find that a 2-inch object glass will gather 100 times more light than the natural eye. To get the light-collecting power of an object lens as compared with the eye, we thus divide the square of the diameter of the lens by the square of $\frac{1}{5}$; or we may merely take the number 25 and multiply this number by the square of the diameter. Thus, a 3-inch objective will collect 225 times as much light ($9 \times 25$) as the unaided eye; the 4-inch telescope will collect 400 times as much ($16 \times 25$), etc. A 3-inch objective thus gives more than twice as much light as a 2-inch, and a 4-inch nearly twice as much as a 3-inch.

The object lens, receiving its normal share of light, and receiving with it an image from without, sends both down the tube of the telescope to be received by the eyepiece. The amount of light, while generous, is fixed in quantity. But the image, upon the eye, is not yet fixed in size; it can be *varied* in size by the different magnifying powers represented in the different oculars. If the power of the eyepiece be great the light received must be spread over a large image and the impression must be dim; if the power be small the light is not so much spread out, or diffused; and, as the parts or factors of the image lie closer together, the light may fall upon the whole with more of concentration. The resulting image is smaller but brighter. It is thus that low magnifying powers involve a relative intensity of illumination, and high magnifying powers involve a relative diffusion, or loss, of light. This is not the *whole* story. Questions of optical theory lie outside the province of this book. It is well, however, for the beginner to appreciate a few of the reasons why, as I have said, the attempt to increase the size of an image in a particular telescope may actually prevent our seeing it. The practical astronomer has always laid stress, therefore, upon the maxim that "the highest power which can be used with advantage is the lowest power which will show the object." In other words, if a power of 50 will show you the thing for which you seek, there is no gain and much loss in crowding on a power of 75 or 100.

### The Astronomical or Reversing Eyepiece

Practically all telescopes of standard quality are provided with two or more astronomical eyepieces. They are usually provided also with a terrestrial eyepiece for viewing objects on land or sea by daylight. This latter is in the longer of the sliding tubes that slip in and out of the main body of the instrument. Removing this tube with its eyepiece,

the shorter tube may be slipped into its place. This shorter tube carries the astronomical eyepieces; they may be slipped or screwed into it, and are interchangeable. Upon each a cap of dark-colored glass is sometimes found. This is for use in viewing the Sun (see, however, par. 2, p. 64) and should be removed, of course, when viewing other objects. First learn to focus with the astronomical eyepieces by *daylight*, directing the telescope to some distant object, preferably on land rather than at sea. Begin with the eyepiece of lowest power. On looking through it the beginner will note that the image is inverted, or "upside-down." This is no reason for indignantly returning the telescope to the dealer as defective,—a course that has been followed more than once. All astronomical eyepieces show an inverted image. The image is so presented by the object lens. It reaches the eyepiece upside-down. It is a simple matter to erect it, if we so desire. This is done, indeed, by the terrestrial eyepiece, for by daylight, and in viewing objects upon the earth, it is confusing and disconcerting to have to view them upside-down. But in the sky, where there is no scene of closely related objects to which we must mentally adjust ourselves, an inverted image makes practically no difference to us. We soon grow used to it.

**TELESCOPE—MODEL A**
*All-Azimuth Mounting*

And such inconvenience as it may cause is more than offset by the fact that with the image inverted we can enjoy more of the light-collecting power of the telescope. For the erection of the image additional lenses must be used—this is one reason why the terrestrial eyepiece is longer and is more expensive than the astronomical—and these additional lenses for the erection of the image necessarily absorb a portion of the light.

We have spoken of the fact that the two or more astronomical eyepieces usually provided with each telescope represent different magnifying powers. But it is well to remember that the magnifying power of the telescope is also determined, in part, by the size of the object lens.* In other words, the result is due to a combination of the lenses at both

* Each lens has always a fixed "focal length." The focal length of a lens represents the linear distance between the centre of the lens and its focus. The magnifying power of a telescope is that of the eyepiece and the object lens in combination; and this power equals the focal length of the objective divided by that of the eyepiece. For example, if the focal length of the objective is 38 inches, and the focal length of the eyepiece is half an inch, the magnifying power of the combination is $38 \div 0.50 = 76$.

ends of the instrument. The objective, however, is fixed; so we secure our changes in magnifying power by changing the eyepieces. And as this is easily and quickly done we fall naturally into the habit of speaking of "40-power eyepieces" or "eyepieces of 60 power." This habit is a matter of convenience. It does not become an inconvenience unless we forget the truth of the case in ordering a new eyepiece, and merely send for a "50-power eyepiece." No one will know precisely what eyepiece we wish unless we also specify the size of the object lens, the length of the telescope tube, and—if possible—the name of the maker. For an eyepiece that will give a magnifying power of 50 on a 3-inch telescope, will give less than 50 on a 2-inch and more than 50 on a 4-inch.

## What Magnifying Powers?

In selecting the astronomical eyepieces for a small telescope it is well to have at least two—and, if the purse permit, a third or even a fourth. Two, however, should be regarded as essential,—one a low-power, for easy double stars, for star-clusters, comets, nebulæ, general star-fields like the Milky Way, and for all objects presenting an extended image. Here the primary requisites are abundant light and a generous field of view,—conditions afforded by low powers and rendered impossible with high powers. An eyepiece of high power will often prove useful for difficult double stars, and for the study of detail upon Sun, moon, and planets.

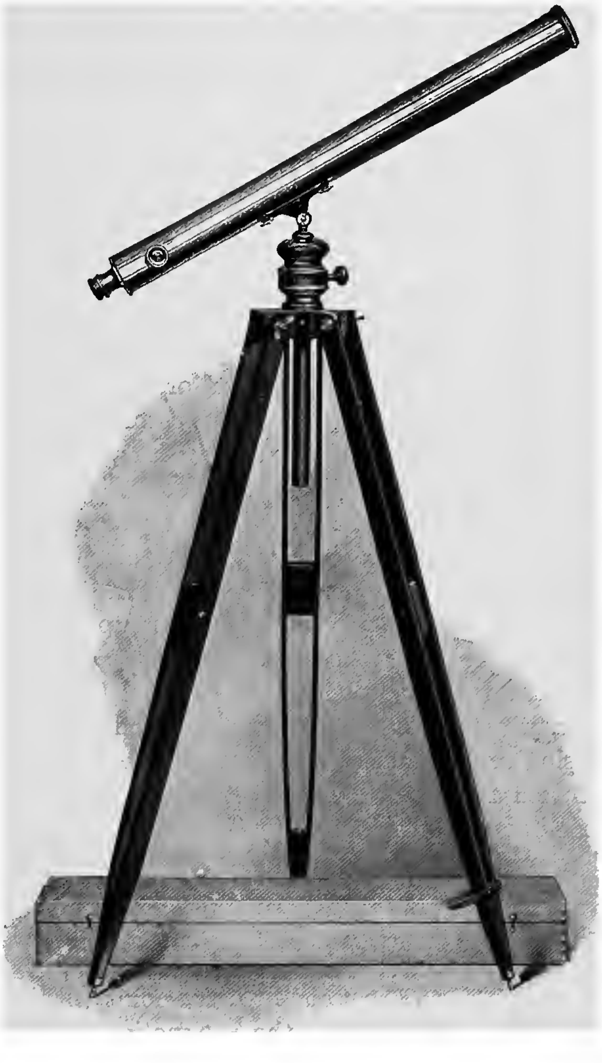
Between the highest and lowest powers it is well, when feasible, to have an intermediate eyepiece, for use under special conditions that may arise while the observer works. Atmospheric difficulties may make the highest power useless on a night when the planets are of special interest; or a double star, too "close" for the lowest power, may require more light than high magnification will permit. Indeed the intelligent observer will find that one of the most interesting phases of his work will be the adaptation of his instrument, from object to object or from hour to hour, to the immediate conditions with which he deals. No absolutely rigid rules may be imposed.

It may be helpful, however, to indicate a series of eyepieces for the sizes of telescopes in popular use. This is here done, distinctly upon the assumption that these suggestions are only approximate and that a variation of a few diameters in any particular case should not be a cause for rejecting a telescope. Indeed, a manufacturer in providing the optical equipment for his instruments may often prove a better judge than any one else. In some cases, however, the manufacturer does not specify the powers of the eyepieces, merely offering a given number (two, or three, or four, etc.) with the instrument,—and leaving it to the purchaser to choose the powers. In such cases, then, these suggestions may prove useful. In selecting astronomical eyepieces the best two powers for a 2-inch telescope would be 25× and 75×; the best three powers would be 25×, 60×, 75×. For a 2¼-inch the best two would be 30×, 85×; the best three, 30×, 65×, 85×. For a 2½-inch the best two, 35×, 95×; the best three, 35×, 70×, 95×. For a 2¾-inch the best two, 40×, 100×; the best three, 40×, 75×, 100×.

For a 3-inch telescope the best two powers would be 45× and 115×; the best three, 45×, 75×, 115×; the best four, 45×, 75×, 115×, 150×. For a 3½-inch the best two, 65× and 160×; the best three, 65×, 95×, 160×; the best four, 65×, 95×, 140×, 160×. For a 4-inch telescope the best three, 70×, 150×, 230×; the best four, 70×, 100×, 150×, 230×; the best five, 70×, 100×, 150×, 230×, 285×.

The series just outlined might be continued indefinitely; but for other instruments the observer will find it easy to apply the general principles suggested by the examples

cited. In a number of cases I should have suggested, for the *lowest* power, eyepieces even lower than the ones indicated, but it is not always easy to secure them. The manufacturers have been under such continuous and general pressure for high powers, and an uninstructed public has been so prone to test every telescope by its mere ability to carry high magnifications, that the makers have not been wholly to blame. But powers for each instrument as low as the lowest prescribed above may usually be obtained, and are fairly satisfactory. The optical limit of lowest power is, of course, fixed by the light-receiving capacity of the eye. The diameter of the average pupil being $\frac{1}{5}$ of an inch, as we have seen, we must employ a magnifying power of at least 5 for every inch of aperture. The low-limit of power for a 3-inch telescope would therefore be 15×. This is the theoretic limit. Practically, however, there are few eyes that can well utilize so large an amount of light. There is also a high-power limit. Astronomers have frequently placed this at 100 for every inch of aperture. Upon this basis an eyepiece magnifying 300 times may be used on a 3-inch telescope and a power of 200 on a 2-inch. Formal tables showing, upon this basis, the double stars that different telescopes will divide have actually been published in reputable books. Nothing could be more misleading, especially to the beginner. "Indeed" says Newcomb, "it is doubtful if any real advantage is gained beyond 60 to the inch."* As the context shows, Newcomb has special reference to a large telescope, 24 inches in aperture, and, as he hastens to declare, his "remarks apply to the most perfect telescopes used under the most favorable circumstances." He then proceeds, in terms too technical for quotation here, to describe some of the inevitable limitations of the telescope. We will deal below, in showing the advantages of low powers, with some of the simpler of these difficulties. It should also be said that the beginner does not have, with the astronomer, the advantages of training,—the trained eye and mind and hand. In the light, therefore, of these considerations it should be clear that the average amateur observer,



TELESCOPE—MODEL B

*Alt-Azimuth Mounting*

* *Popular Astronomy*, by Simon Newcomb, LL.D.; New York, American Book Co., p. 144.

especially at the beginning, cannot use to advantage a power of over 35 or 40 for every inch of aperture. This is the maximum, from the standpoint of practical experience. And in most cases the beginner will do well, especially at first, to work with eyepieces giving powers still lower. He will not thus see less than with higher powers; he will actually see more, and what he does see will be seen with greater clearness and with far greater ease and pleasure. As he gains in experience he can begin the use of eyepieces of higher power.

### The Telescope Mounting

The telescope tube is supported by a stand or tripod. Sometimes the instrument is merely provided with a stand of the "pillar and claw" type as shown in our illustration called Model A. This form of support is intended for use upon a table or upon a broad window sill. For packing or storing with the telescope, it has decided advantages but it is not usually a satisfactory model for serious work. Many of its disadvantages, however, can be overcome by careful managing. If it be used upon a table, see that the table rests solidly and squarely on the ground or floor so that every possible source of unsteadiness may be provided against. Telescopes of this general type may be had of a number of makers and dealers, in sizes ranging from a "2-inch" to a "3-inch."

The telescope marked here as Model B represents a more efficient type of tripod and is not much more expensive than the preceding. By far the greatest number of small portable instruments are mounted in this way. Each manufacturer varies the type a little, some making the tripods lighter or heavier than others, and securing the two motions necessary—a cross motion and a motion up and down—by different mechanisms. But all such mountings, from whatever maker, are extremely simple in design, are quickly understood and easily handled. While Model C represents the same general principle, it is heavier, its structure is more stable, and it possesses a more elaborate mechanism for increasing or decreasing the height of the telescope. The instrument here shown is provided with a "finder,"—a miniature telescope at the eyepiece end of the tube for aiding the observer in bringing objects into the field of view; § 13, p. 112. Tripods of this type are less portable than Models A and B but possess greater rigidity and steadiness.

The models thus far mentioned, A, B, and C, represent, in principle, what is called an "alt-azimuth" mounting, a mounting permitting a motion in altitude and a motion "in azimuth" (or a motion up and down and right to left). The two motions permit the direction of the telescope to any point within convenient range of the observer. In Model D, however, we find the two motions necessary to the telescope secured in a somewhat different way. This represents what is known as an "equatorial" mounting. Here, when the instrument is properly placed and adjusted, the fundamental axis is *fixed* parallel with the axis of the earth, running north to south. Free movements on the other axes of the instrument now give to the telescope the two motions provided by the preceding models. Assuming, for example, that the large end of our instrument points south, an observer stationed at the eyepiece will be able, when a star to southward has been brought into the field of view, to follow it in its course with only one motion of the telescope, the motion from east to west. This work can also be performed by an additional attachment called a "slow motion"; note the rod extending outward between the tripod and the eyepiece. And even this function is discharged, in instruments still more elaborate, by a "driving-clock" which, moving the tube in correspondence with the diurnal motion of the earth, enables the observer without effort to follow the course of the object in the sky. The "equatorial" mounting, with or without a driving-clock, is often pro-

vided with "hour circles." Such an equipment ensures the accurate direction of the telescope to any object in the heavens, whether or not it may be seen by the unaided eye, provided its Right Ascension and Declination (the astronomical equivalents of longitude and latitude) are known. By a system of graduated circles adjusted to the axes of the telescope the instrument may be directed first to the proper Declination of the object, and clamped; it may then be turned to the object's Right Ascension (in hours, minutes, etc.,—see note 14, p. 32). The star will thus be brought within, or very nearly within, the field of view. Indeed it should now be precisely in the field of the telescope if all the conditions of the case are accurately met. As most of the readers of this book will not possess instruments with hour circles I merely refer those who wish to make further study of their use to the volumes listed in the footnote.* To meet, however, the needs of instruments so equipped the places of the objects listed in the Observer's Catalogue of the present volume are indicated by Right Ascension and Declination, as well as by constellations. Such references are also of value to those who may use the charts of the celestial sphere at the close of the book, or who may desire to make use of celestial globes or larger star maps. In the location of the objects of observation, even when the telescope is without hour circles and not equatorially mounted, such references become increasingly helpful.

TELESCOPE—MODEL C
*Alt-Azimuth Mounting*

Which of these various types of mounting shall the beginner purchase? The answer—for all cases—is not easily given. Each type has its strong points. Model D, if fitted with hour circles, should have the preference for advanced students, even though the instrument be without a driving-clock. But, in order to possess any real advantage over the simpler mounting represented in Models B or C, it must be accurately adjusted for latitude; it is heavier, more complicated, and not so easily managed. For the *beginner*, therefore, I do not hesitate to recommend the general form shown in Models B and C. These are purely illustrative. Both types of mounting are made by many different manufacturers in a number of designs; all representing the same principle of construction. The alt-azimuth type is less expensive as well as less complicated than the equatorial, and it is adapted, if well made, to all the ordinary needs of the amateur.

* See Chambers' *Handbook of Astronomy*, vol. i., the Oxford Press, 4th Edition, New York and London; Gibson's *Amateur Observer's Handbook*, Longmans, Green & Co., New York and London, p. 36 fol.; Todd's *New Astronomy*, New York, American Book Co., p. 53.

## The Telescope for the School

In teaching the circles of the celestial sphere and in illustrating the theory of the science, the instructor may desire an "equatorial" mounting, but in the practical work of observation, in introducing others—by simple object-lessons—to the pleasure and practice of viewing the things of the sky, the less elaborate mounting will meet the requirements even of the teacher. For high-schools and colleges I would strongly advise, where financially possible, a telescopic equipment of three or four small instruments, rather than one very large one more elaborately mounted. Of this group of telescopes, the largest may have an aperture of 3¾ or 4 inches and be mounted equatorially (if desired); the others may be of 3 inches in aperture (or even smaller) and on alt-azimuth mountings. Such an equipment, while not meeting an ambitious desire for an "observatory," will do far more than a great observatory instrument for the actual needs of the students. These, at least in earlier years, can hardly expect to become astronomers in the technical sense, but they should be permitted to share the interests and enthusiasms that follow from the direct personal observation of the familiar celestial objects. A little experience of this kind will often awaken ambitions for higher and broader work; and it has its illustrative value for teachers as well as scholars. An equipment of small instruments has the following advantages over a single large expensive telescope:

(1) It is *possible* in many cases in which the large telescope with elaborate mounting is impossible; many a small institution which has no local provision for the large telescope can provide for the storage and keeping of a number of smaller ones.

(2) This equipment will permit the simultaneous instruction. within a short period of time, of a larger number of observers.

(3) With it, the really interested teacher can more quickly train adequate assistants from volunteers among the older pupils or from among associate teachers—if assistants should be necessary.

(4) The equipment of smaller instruments may be quickly unpacked and adjusted for use by one or two of the older pupils,—or even by an intelligent janitor, if need be. When work is completed the telescopes may be as quickly repacked, and stored.

(5) The suggested equipment is far less expensive than a single large telescope on a stationary stand with an elaborate mounting.

(6) Such a provision, even in institutions where there are large telescopes for observatory work, will free these larger instruments for their proper service under the observatory staff, and yet provide for the legitimate desire on the part of the students and others to see for themselves the objects of astronomical interest. Nearly all the characteristic objects of observation, see p. 3, can be seen by the beginner with far greater satisfaction in a small telescope than is commonly supposed.

(7) The *experience* acquired will be all the more useful because gained from practise with such instruments as the average student may some day hope to possess.

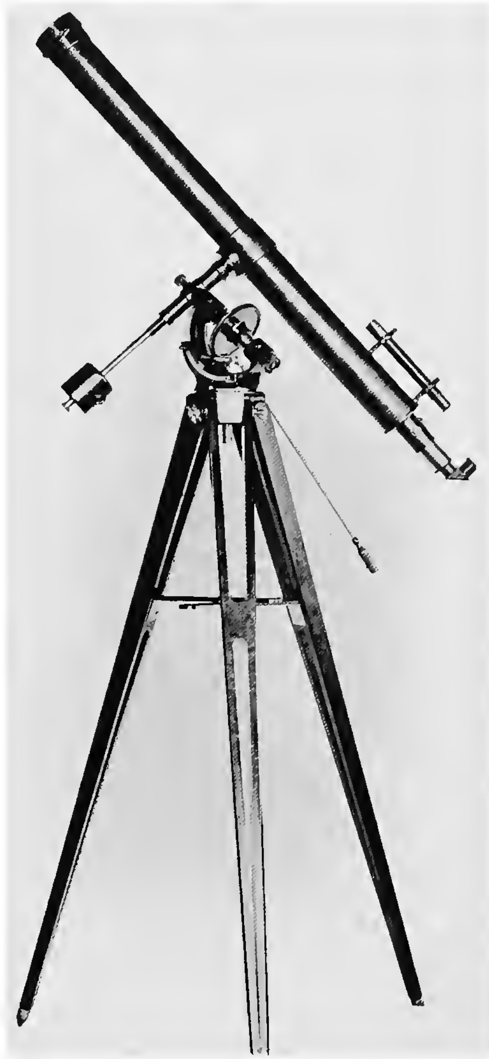
(8) The problem of bringing the telescope into the work or the recreation of the average school often resolves itself into the practical problem of finding the teacher who can undertake it. The plan suggested—a small group of several smaller instruments simply mounted—requires no special training. Such an equipment can be readily utilized.

## First Observations—The Advantage of Low Powers

The telescope is usually delivered to the purchaser in a box; the tripod being packed separately. In unpacking the metal parts from the box, note how the pieces lie, in order

that they may be easily replaced when you desire to return the instrument to the case. Fixing the tripod in the open air for your first observations, see that its feet are evenly spread and that it is truly centred. All that contributes to its steadiness will help you to see; all that interferes with its stability will make good seeing difficult. Whatever the form of the mounting, it should be strong and secure. A good, rigid support for the instrument is of fundamental importance.

Almost the first question to arise will be, "What shall we look at?" Choose at first something quite easy. Let it be at night, if possible; the Sun is a poor first object. If the moon is in the sky, turn first to that. If the time be a winter's evening and Orion be in the sky, try an easy double star,—Delta ($\delta$), the top star of the Hunter's belt. See the Key-Map, p. 41 or 45. The star Zeta ($\zeta$) in the Great Dipper, see any northward Key-Map, is also a fine first object. If the season be the late spring or early summer, try the star marked Beta ($\beta$) in Scorpius; pp. 53 and 57. If one of the planets (Jupiter or Saturn) be well placed for observation, these are also superb first objects; see pp. 88 and 91. Mars and Venus are not so "consistently" easy.



**TELESCOPE—MODEL D**
*Equatorial Mounting*

After removing the brass cap from the large end of the instrument, try to get a clear focus on the object, using the astronomical eyepiece of lowest power,—the eyepiece with the largest aperture, and with the largest exposure of glass on its interior surface. As you look through the telescope trying to find and view your first objects, you will perhaps be more or less baffled by certain troublesome impressions. The statement of these will illustrate the reasons for the repeated warnings to the beginner against high magnifying powers.

If it were optically possible for the telescope to magnify the object *alone*, and to preserve it as a large image in a large well-lighted field, then we should want our magnifying power high, indeed the very highest. But this is not possible. Optically, there are some things as impossible to a telescope as for a good watch to tick seventy seconds to the minute. In magnifying the object, the very power used reduces the field of view in which it lies, the amount of light which illuminates this field, and magnifies not the object alone but every factor which involves or affects it as an image. The impressions to which I have referred are, therefore:

1. The impression that the world into which you are peering is dark, gloomy, and tractless. This impression is the more intensified, the higher the power you employ.

2. The impression, after you begin to see your way through your telescope, that the

circles or areas covered by your instrument are pitifully small. The smallness of the field you command makes it hard to find the object you are seeking. The field becomes smaller and this task of *finding* things becomes harder with the increase of magnification.

3. The impression that an object once found is wilfully determined to flit from the field of view as soon as sighted. This is partly due to the unsteadiness of your hand. Just as a power of 100× will magnify the object, it will also magnify by 100 times, every touch or vibration of the hand, every disturbance caused by the wind or by heavy walking near the tripod. The lower the power, the smaller these exaggerations of motion.

4. The impression, even when the hand is removed and all is still, that the object is resolved to race away. There is now no touch of the hand, no unsteadiness, no vibration,—and yet "the thing *will* not stay!" There is one motion, however, that we may have forgotten. We know that all the objects of the sky, however stable they may be, *seem* to be slowly carried from east to west. This is due to the revolution of the earth on its axis. This rate of motion does not seem, superficially, very rapid; but multiply it by 100, or by 200, or by 300. When this apparent motion of the stars or moon or sun is thus magnified, we can readily see how quickly such objects must move across that little circle of sky which we have caught within our telescope.

5. The impression that as we attempt to follow an object in the field of view and to keep it near the centre, the object is deliberately "contrary," shifting to right or left in a direction precisely the reverse of the intention of the hand. This is based upon fact; all directions are reversed in the field of an astronomical telescope. The fact cannot be altered; but the larger the field the less likely we are to lose the object by small false directions of the hand. Low powers give this large field and permit an easier mental adjustment to the conditions.

These impressions cannot all be removed at once by the use of eyepieces of low power, but they can be corrected. Thus the beginner can *begin* without a sense of despair and with somewhat of a sense of conquest. *This sense of conquest will rapidly increase;* and, as it increases, he will find increasing pleasure in his instrument. He will also find that he can, with more experience, use higher powers with advantage—changing his eyepieces and adapting the magnification of the telescope to different objects and to varying conditions.

## Some Practical Notes.

1. A dark-colored cap will sometimes be found attached to the astronomical eyepiece. This is for use only in viewing the Sun. It should be unscrewed and removed from the eyepiece in viewing other objects. See also p. 64.

2. Almost all observers work better while seated. Use an ordinary straight-back chair. Take the time and the necessary care to place yourself in a comfortable position. Strained postures and inconvenient attitudes are directly embarrassing to clear vision.

3. Be deliberate. Try not to hurry from object to object. Look with the mind as well as with the eye; this will help the eye as well as the mind. Try to reflect quietly upon the object under observation, returning to it repeatedly and noting any special peculiarities that may suggest themselves.

4. Street lights are sometimes a sore trial, especially when seeking to view objects near the horizon. A small sheet of cardboard slipped over the eyepiece end of the telescope will often prove a protection from their interference. Access to a good roof is an even better means of escape from such annoyances.

5. Work from smaller tasks to greater. The beginner may keep himself in a state of

nervous discontent by a ceaseless expenditure of energy in the pursuit of objects just at the limit of visibility. Or he may take a wiser course, and prepare for these tests of vision by first learning to appreciate the many interesting objects within the normal capacity of his eye and his instrument.

6. In winter it is advisable to be warmly wrapped—for the physical exercise which so often protects us from exposure is missing while we are seated at the telescope. There are many observers who do not scorn the use of a hot brick as a foot-warmer. This if well-wrapped will keep warm for some time; and, when its heat is gone, another may be substituted.

7. To the beginner, the *finding* of objects with the telescope will at first seem difficult. If the eyepiece of lowest power is used, this will afford a wide and well lighted field of view and the object can be located more easily: a higher power, if desired, may then be substituted without "losing" the object. A slight re-focusing will be necessary. As experience increases, the finding of the desired objects becomes less difficult and is quickly accomplished.

8. It is usually best to meet the problem of "thick" weather by retreat,—unless you have much time to waste and much good temper to employ. As the telescope magnifies mist and fog as well as the objects of interest, it is at its worst under such conditions. If one will persist in working, and the mist be not excessive, the best objects under such conditions are the moon and the brighter planets, particularly Saturn—if these be in the sky. Whatever the atmospheric conditions, it is well—before beginning observations—to make a brief list of the objects to be noted. This will serve as a working memorandum and will usually save time. Begin with "easy" objects; not attempting things more difficult till the eye has been accustomed to the darkness.

9. Cleaning the lenses of an instrument is sometimes necessary. But it is best to use your lenses so carefully—protecting them from dust etc.—that this necessity may be rare. They bear a high polish. This may be seriously damaged by injudicious wiping and rubbing. Scratches are far worse than a little dust. If dust accumulates remove it gently with a very soft camel's-hair brush, such a brush as may be bought for five cents at any druggist's. Special paper for cleaning lenses is often found at the optician's. If of the very best quality it may be tried, but much of it is worse than useless. The lenses may sometimes be dusted off gently with an old soft cambric handkerchief. The objective may be unscrewed from the tube, if absolutely necessary, but the two lenses of which it is composed should never be taken apart except by the manufacturer.

10. The habit of pointing a telescope from the window of a room is not to be commended. Still less should a telescope be pointed through a pane of glass, however clear. Distortion must result. The instrument should be taken into the "open," even if one can do no better than place it on a veranda. If this be impossible and a window must be used, all light in the room should be turned out, and time should be given for the pupil of the eye to grow accustomed to the dark. In the dark the pupil grows larger and the eye keener. The temperature in the room should also be permitted—if possible—to approximate the temperature outdoors, if the telescope is to do its best work. The larger the instrument, the more need there is to let the air in the tube come to the temperature of the air outside, that the images seen in the telescope may be steady and clear.

11. For this reason it is well to permit the telescope to "cool off" for a few minutes, if taken from a warm room in winter and set up outside. Time should also be given to the pupil of the eye to dilate in the duller light of the out-of-doors. Good work cannot be done with an eye contracted by the illumination of a brilliantly lighted room, peering

through a telescope in which the hot air is in process of "boiling-down" to the temperature of the outer cold. Sir John Herschel, before attempting to verify his father's observations on the satellites of Uranus, kept his eyes in total darkness for fifteen minutes. Such extreme precautions are not necessary with small instruments; but the general suggestion is important.

12. The beginner will sometimes feel the telescope to be a strain upon the eyes. Closing one eye while looking through the instrument with the other eye is at first a weariness to both. This weariness often wrongly suggests that something is the matter with the eyes. These difficulties, however, are almost entirely muscular. The proper muscles soon become used to the new way of seeing; and the observer soon finds that he can use his instrument for long periods with no sense of strain or discomfort. Near-sighted observers need not retain their glasses; the instrument, with proper focusing, will correct the difficulty: the eyepiece should be pushed a little farther into the tube. Even with normal eyes the one used most actively may be soon wearied. If so, it may be given brief intervals of rest, and the need for these will decrease as experience grows. A few observers find that an eye-cap of dark cloth over the unused eye is an advantage. One needs to avoid the undue exhaustion of the nervous and muscular forces of the eye, but this danger is no greater at the telescope than at any other interesting work. In many cases the vision is stimulated, trained, and positively improved.

13. The optical equipment of a telescope usually includes at least one terrestrial and two or more astronomical eyepieces. If the terrestrial eyepiece is omitted, the purchaser may fairly ask a larger astronomical equipment; for its money value—compared with the latter—is about as 2 to 1. Extra attachments, usually at additional expense, may be had,—such as a diagonal eyepiece for viewing objects too near the zenith for convenient observation, and a "Herschel" eyepiece for reducing the light and heat of the Sun to the eye. The latter is discussed in the chapter on the Sun. The diagonal eyepiece makes the finding of objects more difficult, and it deprives the observer of the sense of *direct* vision. Many find such an attachment of great convenience, however, in viewing objects that are too high up for comfortable study with the ordinary equipment. The attachment is "popular," though its cost is high in proportion to its actual working value. The diagonal eyepiece is shown on Model D, but it may also be obtained with practically all telescopes over two inches in aperture. On Model D and also on Model C is shown a "finder," a miniature telescope placed near the eye-end of the larger instrument. With its low-power eyepiece it affords a very large field of view. This is divided by two cross wires which by their intersection mark the centre of the field. The finder is so adjusted that when an object is brought to the centre of the field of view in the finder, it will be found at the centre of the field in the telescope proper, the two centres being coincident. This attachment is extremely desirable on instruments over three inches in aperture. Telescopes of three inches and under do not need it. In the finding of objects, as has been already suggested, a low-power eyepiece may be used on the telescope itself, and, when the object is found, a higher power—if desired—may be substituted.

14. First impressions are sometimes disappointing. The distance of the stars is so great, see p. 9, that the facts transcend all our ordinary standards of comparison. When we are told in one sentence that a celestial object is at least 1000 times larger than our Sun, it seems wholly absurd to learn in the next sentence that though we may use upon it a magnifying power of 100 diameters the telescope can show it to us only as a brilliant point of light. Let us suppose, however, that we were able to use a telescope magnifying not 100 but 10,000 diameters. As such a telescope—even if its construction were

possible—would magnify all the conditions of atmospheric obscurity or disturbance (as well as the star) no one could use it. But on the assumption that we could use it, what would it do for us? It would bring a star that might be 10 million million miles from us to an apparent distance of 1000 million miles. That is not very near! But there is no star so near as 10 million million miles. The very nearest is 4.3 light-years, or 25,000,000 millions of miles away; and no star so near as that can be seen from the latitudes of Europe or North America. Most of the stars are at far greater distances. As we bear these facts in mind, we need not be surprised if the telescope does not make any of the fixed stars assume the proportions of a tea-cup. In the case of the objects of our solar system—the Sun, the moon, the planets—an apparent enlargement of the image may be had. But there are many who find disappointment even here. Says Webb: "In viewing Jupiter in opposition with a power of 100, they will not believe that he appears between two and three times as large as the moon to the naked eye; yet such is demonstrably the case. There may be various causes for this illusion;—want of practice, of *sky-room*, so to speak, of a standard of comparison. A similar disappointment is frequently felt in the first impression of very large buildings; St. Peter's at Rome is a well-known instance. If an obstinate doubt remains, it may be dissipated forever when a large planet is near enough to the moon to admit of both being viewed at once—the planet through the telescope, the moon with the naked eye."*

15. A telescope equatorially mounted, having hour-circles but with no sidereal clock, may be directed to an object invisible to the naked eye by the following method. Note and record the *difference* in Right Ascension between the required object and some *known* object that may be readily recognized. (The beginner should remember, in calculating the difference in R. A. between two objects, that if this difference is greater than 12 hours the number 24 must here be added to the smaller R. A. before subtracting.) We proceed on the assumption that the object sought is toward the south. If the R. A. of the object sought be greater than that of the known object the former will be farther east; if the R. A. of the object sought be smaller, that object will be the farther west. Using your eyepiece of lowest power, direct the telescope to the known object, bring it to centre of field, and read the hour-circle. Now move it east or west, as need may require, until the index of the hour-circle has moved through a distance equivalent to the difference in the Right Ascensions. Now set the Declination circle, and the required object will be found within the field. Gibson wisely suggests that the known object be selected, if possible, on the same side of the meridian as the object sought.

16. Telescopes variously mounted and fitted with adequate eyepieces may be had in the United States at the following retail prices. These prices are not to be taken as from the catalogue of any particular manufacturer. They are to be regarded as rough approximations, here introduced merely as a general guide to the purchaser.

Telescopes of from 2 inches to 2¼ inches in aperture may be had at from $60 to $85, according to quality and type of mounting. There is usually not much difference in cost between a 2-inch and a 2¼-inch, and—other things being equal—the 2¼-inch is, of course, to be preferred.

The same consideration applies to telescopes of 2½ to 2¾ inches in aperture. These may be had at from $65 to $120, according to quality and type of mounting. The simple mountings cost less, and are usually efficient enough to meet the needs of the average observer.

* *Celestial Objects for Common Telescopes*, T. W. Webb, M.A., F.R.A.S., vol. i., p. 16, ed. of 1907; Longmans, Green & Co., New York and London.

Telescopes of 3 inches in aperture fitted with one terrestrial and at least two astronomical eyepieces can be had at from \$75 to \$170. Here again the simple "alt-azimuth" mounting is quite adequate for all ordinary purposes.

The prices of telescopes over 3 inches in aperture I do not attempt even to suggest—the variety is so great and the range of values is so large. If one desires, one can put as much as a thousand dollars into a 5-inch portable telescope.

There are also instruments on the market at prices lower than any here quoted. Without judging them, I have preferred to speak only of values that are personally known to me. Teachers and all who are on the purchasing committees of schools and colleges will take satisfaction in learning that the high customs tariff on telescopes of foreign manufacture is not applicable to instruments purchased for the use of educational institutions. Deductions, therefore, from the prices above quoted—ranging from 20 to 35 per cent.—are not infrequently made. The transaction, however, must represent a direct importation, must be in the name, and for the use of, the institution, and instruments thus imported must not be for sale.

17. A few final notes are here thrown together.—In using the Key-Maps for the telescope, the beginner should first read the accompanying notes under the Night-Chart on the pages opposite.—Always remember, in using any of the Key-Maps, to begin as near as may be feasible at the *centre* of the map, working from the centre outward.—While the telescopic objects are classified roughly for (I) the Opera-Glass and the Field-Glass, (II) the Two-inch Telescope, and (III) the Three-inch Telescope, these divisions are necessarily somewhat arbitrary. An object listed for a 2-inch, may be seen to even better advantage in a 2¼, or 2½, or 2¾, or 3-inch; and some of the objects classified for the 3-inch may be well observed, under good atmospheric conditions, through smaller telescopes,—especially if the observer has had the advantage of a little experience. Those, moreover, who possess 4-inch or even 6-inch telescopes will find that the selected objects are not less interesting or less beautiful because adapted to smaller apertures,—any more than a drop of water is less interesting as we increase the range or refinement of the microscope. Should the observer wish to work in entire independence of the classifications under the Key-Maps, he has only to turn, in the Observer's Catalogue, to the *constellation* desired, where the best maps are indicated and all the important objects noted.—The beginner is reminded that in viewing the *full* moon there are certain advantages in using the terrestrial rather than the astronomical eyepiece; the additional or erecting lenses serve to reduce the excessive brilliancy of the object. See pp. 70, 71.—Teachers who may wish information as to the adaptation of this book to their educational work (either alone or for *supplementary use*) may obtain a special circular on application to the author, in care of the publishers.

"Herbert Spencer has somewhere reminded us that the crowbar is but an extra lever added to the levers of which the arm is already composed, and the telescope but adds a new set of lenses to those which already exist in the eye. In a very deep sense all human science is but the increment of the power of the eye, and all human art is the increment of the power of the hand. Vision and manipulation,—these, in their countless indirect and transfigured forms, are the two coöperating factors in all intellectual progress."—JOHN FISKE; *The Destiny of Man; Chapter VII.*

NEBULA IN SAGITTARIUS, KNOWN AS MESSIER 8

*From a photograph taken at the Yerkes Observatory*

# VIII. A Brief Observer's Catalogue of Telescopic Objects

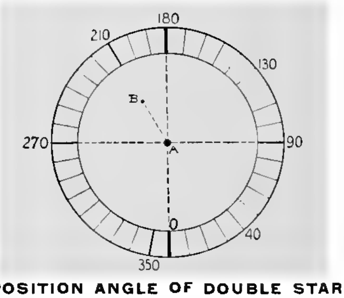
∴ This Catalogue is limited to objects of the Stellar World; for the objects of the Solar System, see Chapter V.

**Explanatory.** The objects discussed under the Night-Charts and Key-Maps, pp. 38 to 61, are there given reference numbers in brackets [ ]. These refer to corresponding numbers in this catalogue. The catalogue will thus be found to contain a good deal of material for which there was not space under the maps. Some of this the beginner may not at first want, but there will be an increasing desire for additional facts as interest and knowledge grow. Here are given, also, the positions of the stars by Right Ascension and Declination—for the use of those who may possess instruments with hour-circles (see p. 107) and for all who may desire to find the places of the stars, in star atlases or in charts of the celestial sphere, with more precision than is possible in a mere general reference to the constellation. See note 14 on page 32.

While the telescopic objects are chiefly noted under the Key-Maps on the right-hand pages, 39 to 61, the beginner should not fail to read *also*, in each case, the matter under the corresponding Night-Chart. A few telescopic objects not noted under the Key-Maps are included in this Catalogue.

Here also will be found indicated the exact magnitudes of the stars. These are given according to the *Revised Harvard Photometry*, 1908. In some cases the magnitudes of the smaller components of the double stars are not given in that list. In such instances they are chiefly taken from the *Sternverzeichniss* of Ambronn, Göttingen, 1907, as stated in the preface to this book. From that compilation I have also taken the estimates of star colors, and where these are omitted in the Ambronn list, I have fallen back on the impressions of Webb or Smyth, except where very subtle distinctions of color have seemed overdrawn. Small instruments do not show, as a rule, any but the clearer and sharper color-contrasts; but much depends, of course, upon the quality and construction of the telescope and on the local conditions of light and air. More still depends on the personal equation of the observer,—some eyes are color-blind; some, if the term may be coined, are color-wild, seeing hues and tints "that never were on sea or land." Avoiding both extremes, the beginner will find much of charm and pleasure in the study of color-contrasts.

Here also are given the *distances* between the components of double or multiple stars, as measured in seconds of arc. Thus the observer may secure a general idea as to the distance at which he may expect to find the members of a composite system. A still greater help in detecting faint companion stars may be obtained from a rough knowledge of "the position angle." The beginner will do well, at the very first, to confine his observation to double stars in which the components are rather widely placed and so bright as to make a knowledge of the position angle unnecessary. To some minds the understanding of position angle measures is very easy; to others it is difficult. The chief point to be remembered is that the amateur may find much pleasure in the observation of such stars without going into the question at all. As the observer comes to take up the subject, a few words of explanation may be useful.




POSITION ANGLE OF DOUBLE STAR

*As shown in Astronomical Telescope, Image Inverted*

*The angle is reckoned from north (below) at zero; through east (90°); and south, 180°; round through 270°, west; to completion of circle at 360°*

First, let us assume that the angle is measured when the star, as we face south, is on the meridian;—that is, at the moment when the star culminates or reaches its highest point in its course from east to west. Let us thus first secure our mental picture of the position angle as an angle measured not at the moment when the star rises or sets or is east or west, but at its upper culmination.

Of the two lines, therefore, which meet at a point and form the position angle, one is the line from north to south running through the brighter component of the culminating star (as the line 0 to 180 in this diagram), the other line is that connecting the two components of the star, A to B. This line is always drawn in imagination from the brighter to the fainter component; and the angle is reckoned, as in the field of an astronomical telescope, from *below* at zero around to B. In our illustration, for example, the position angle of the double star A–B is 210 degrees.

We learn in this way the *direction* in which to look for the fainter component of a double star. Delta ($\delta$) in Corvus, for example, has almost the same position angle as that shown in our diagram. In the sketch given on page 26, Delta ($\delta$) is the *brighter* of the two stars at the upper left-hand corner. The smaller star there shown should not be confused with the telescopic companion. When Corvus is due south or approximately south, see position B, page 26, the small component will be found upward and to the left,—about as in our diagram here. As Delta ($\delta$) rises—or when the constellation, p. 26, is at position A—the position angle is of course unchanged but the apparent direction which it indicates will vary with the position of the group. At A, therefore, the telescopic companion will appear lower down and toward the left. As the star swings westward to position C, page 26, the small companion will appear upward and to the right.

Turn now to page 25, and note the case of Delta ($\delta$) in Orion, the uppermost of the three stars running diagonally through the square. The position angle of this star is 0°. It might also be written 360°, as we may see from our diagram, p. 116. This means, of course, that when Orion is at position B, due south, the fainter component is directly below the brighter. We may see, however, from the illustration on page 25, that when Orion is eastward, at position A, the small companion to Delta ($\delta$) must appear below, but to the right; and that when Orion is at position C, it must appear below and to the left. For the apparent direction of the companion will naturally change, as in the case already cited, with the changing "slant" or inclination of the group. This will become quite clear with a little actual experience in observation.

In studying our diagram of a position angle, the reader should note that it is drawn for use as the observer faces south. In facing northward the beginner should remember that since the zero-point must always be toward the north pole, the top and bottom of the diagram will be reversed for stars culminating between the pole and the zenith. For the northward stars when *below* the pole, the diagram requires no inversion.

References will sometimes be found in this catalogue to double-stars as "doubles," to a star with three components as a "triple," etc. In many cases a double-star is known to represent a system in which both the components are in revolution about a common centre of gravity. Such doubles are called "Binaries." All binaries are double, but all doubles are not necessarily binaries. References will also be found to "spectroscopic" binaries. These are binary systems in which the components are so near that their division or separation can be detected only by the spectroscope—being too close together for the telescope to show them as separate objects. A full discussion of the spectroscope and of its marvellous revelations lies outside the plan of this book; the reader may find such information in some of the volumes noted on page 144. Here it may only be crudely said that these results are obtained in the case of each star by the study of the composition and action of its light. Investigations also conducted with the spectroscope have told us that the stars have besides their "apparent" motions (such, for example, as the motion from east to west caused by the revolution of the earth) and their "proper motions" in space, see page 139, definite individual motions in the line of sight, motions directly toward, or directly away from, our solar system. When the reader finds, therefore, in this catalogue that a particular star is said to be approaching the earth or receding from the earth at the rate of 10 or 15 miles a second, it should be understood that the instrument which brings us such results is not the telescope but the spectroscope. The facts as to the actual movements of the stars are so striking that they might awaken our alarm but for the consideration that the stars are almost inconceivably far away, so far indeed that these movements may possess for us an element of interest but not the least element of anxiety. The same consideration should be borne in mind in thinking of the "proper motions" of the stars; p. 138. For the stars are not really at rest. They seem so to be, because of their great distance from us. But most of them, like the Sun itself—our own star, —are moving through space at high velocities.

References, therefore, will also be given here to the *distance* from us of certain of the stars, and a table dealing more fully with the data will be found on page 139. The instrument by which the most trustworthy of these results have thus far been obtained is a modification of the telescope called the heliometer. Other methods, some of them employing photography, for the determination of star distances are now being matured.

The first association of the stars into constellations or star-groups is prehistoric. Some of the most familiar—such as Orion, the Pleiades, the Hyades, as well as the stars Sirius and Arcturus—were known to Hesiod (c. 800 B.C.) and they appear in Hesiod as already well known and long established. The earliest formal lists are those of Eudoxus and Aratus (c. 400 and c. 270 B. C.) though it is to Ptolemy (150 A. D.) that we owe the full list of 48 constellations familiar to the ancient world. Of these, the most important are those of the Zodiac; see p. 80; namely, Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpius, Sagittarius, Capricornus, Aquarius, and Pisces. Those north of the Zodiac in Ptolemy's list were: Ursa Major, Ursa Minor, Draco, Cepheus, Boötes, Corona Borealis, Hercules, Lyra, Cygnus, Cassiopeia, Perseus, Auriga, Ophiuchus, Serpens, Sagitta, Aquila, Delphinus, Equuleus, Pegasus, Andromeda, Triangulum; and south of the Zodiac as follows: Cetus, Orion, Eridanus, Lepus, Canis Major, Canis Minor, Argo, Hydra, Crater, Corvus, Centaurus, Lupus, Ara, Corona Austrina, and Piscis Austrinus. The myths or legends connected with the more important of these are given in this Observer's Catalogue in their Greek forms,—though the Greek version is often but the recasting of an earlier myth.

**Abbreviations.** The objects listed are grouped by their constellations, in alphabetical order. First, comes the name of the constellation. Then follow page references to the Key-Maps in which it is to be found for observation in the evening sky. Then come references to N. H. or S. H. (northern hemisphere or southern hemisphere), indicating the mean Right Ascension (R. A.) and Declination (D.) of the group, for reference to the hemispherical maps at the close of the volume. As the map of the northern hemisphere contains a large overlap of the southern sky, the abbreviation N. H. at *this* point does not necessarily mean that the object is north of the equator but merely that reference is made to the first (and larger) of the two maps. See note 14, p. 32. The celestial equator should not be confused with the ecliptic; it will be found to run through Hydra, Orion, Aquila, Serpens, etc. The letters S. H. refer to the map of the southern hemisphere, the smaller of the maps at the book's close.

In writing of the double or multiple stars, the letters A, B, C, etc., usually refer to the components in order of brightness. The word "distance" is used for the *distance* between such components; and the letter p. for the position angle. The abbreviation *Mag.* refers to the magnitudes of the stars;— not their physical size or their actual luminosity, but their relative brightness as seen with the unaided eye or with the telescope. In the case of double stars, the position assigned (in R. A. and D.) is for the brighter component; and for the year 1900. Following recent usage, the fractional parts of a minute (in noting R. A.) are here expressed not in seconds but in decimals. One minute and thirty seconds, for example = 1.5 m.

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**A′-cher-nar,** see [175].

**Al-dĕb′-a-ran,** see [381].

**Al-tair′,** see [21].

1.—**An-drŏm′-e-da** (Maps pp. 55, 43, 61, 41. N. H., R. A. I h., D. +40°). A fine constellation lying between Perseus and Pegasus, its brighter stars forming an almost straight line.

According to the Greek myth, Andromeda was the beautiful daughter of Cepheus, king of the ancient Æthiopia, and his queen, Cassiopeia. The queen in the pride of her own beauty sat one day enthroned by the sea, plaiting "ambrosial tresses." There, in the hearing of the sea-nymphs, she boasted that she was fairer than they. Deeply enraged they succeeded in having a sea-monster sent to ravage the coasts of the kingdom. Appealing for help, Cepheus and his queen were informed that the penalty could be averted only by exposing their daughter, Andromeda, as a prey to the monster. She was chained to a great rock by the sea to appease him. There she was seen by Perseus, returning from his victory over the Gorgon. The head of Medusa, which turned all who beheld it to stone, he bore in his hand. Calling to Andromeda and bidding her to avert her face lest she perish also, he turned the sea-monster into a huge rock. Then cleaving with his sword the chains which bound the wrists of the maid, he bore her away as his bride. At death they were placed with Cepheus and Cassiopeia among the stars. The story is finely told by Charles Kingsley in his *Greek Heroes*. A later legend finds in Cetus, the Whale [110], the Monster of this older myth; and in Pegasus, the Winged Horse [301], the steed on which Perseus bore Andromeda away.

2.—The famous nebula, M 31, is not conspicuous in small instruments, but of great interest. R. A. 0 h. 37.2 m., D. +40° 44′. An illustration of the nebula will be found on p. 20. The estimate of its dimensions as given on p. 21 is based on an assumed parallax of 0″.01 (see *Introd. to Astronomy*, F. R. Moulton; New York; edition 1910, p. 541), and is probably an understatement rather than an overstatement. The actual form of the nebula is probably less oval than shown in the engraving. Some observers regard the oval shape

as wholly due to the way in which the object is tilted to the line of sight, but that its form is strictly circular is highly doubtful. Its appearance in a small instrument is somewhat disappointing. The striking and beautiful impression given by the camera is due not only to the efficiency of the telescope employed but to the long exposure of the photographic plate. This is the largest of the spiral nebulæ. The great nebula of Orion [294] is quite as large, if not larger, but irregular in form.

3.—Gamma ($\gamma$) is a double star, one of the most beautiful of telescopic objects. It forms a right-angled triangle with the stars Beta ($\beta$) and Alpha ($\alpha$) of Perseus; or it may be found by running an imaginary line from Polaris to Epsilon ($\epsilon$) in Cassiopeia and continuing it an equal distance. Mag. of components, 2.3 and 5; A orange, B emerald; distance = 10″; p. = 63°, R. A. I h. 57.8 m.; D. +41° 51′. B is also a double in a large telescope. The Arabic name for Gamma ($\gamma$) is Alamak. The star is approaching the earth at the rate of 6.84 miles a second or 410 miles a minute. See Table, p. 139.

4.—Pi ($\pi$), a double star, mag. of components, 4.5 and 9; A white, B blue; distance = 36″; p. = 174°; R. A. 0 h. 31.5 m.; D. +33° 10′. It is interesting to note that this star is receding from the earth at the same rate of motion at which Gamma ($\gamma$) is approaching, 6.84 miles a second; see above.

5.—The little star marked *56* is an easy double; mag. of components, 6 and 5.8; both yellow; distance = 181″.6; p. = 301°; R. A. I h. 50.2 m.; D. +36° 46′.

**An′-ser,** see Vulpecula [425].

**Ant-ā′-res,** see [351].

**An-tĭ′-no-us,** see Aquila [20].

10.—**Ant′-lia,** the Airpump. (Map p. 49. S. H., R. A. X h.; D. — 30°.) An unimportant southern constellation, too low in the sky in our latitudes for satisfactory observation; few objects of interest.

15.—**A-qua′-ri-us,** the Water-Bearer (Maps pp. 61, 57, 41. R. A. XXII h.; D. — 10°). A large constellation, important because lying in the Zodiac or pathway of the planets, see p. 80, but it is not conspicuous, having no stars greater than the third magnitude.

16.—The globular cluster marked M 2 is not brilliant. Located by imaginary line from Zeta ($\zeta$) in Capricornus to Beta ($\beta$) in Aquarius, and slightly continued. R. A. XXI h. 28 m.; D. — 1° 16′.

17.—The star Zeta ($\zeta$), at the centre of the Y-shaped figure marking the mouth of the "water-jar," is a strikingly interesting double, the components being of almost the same magnitude. Mag. of components, 4.4 and 4.6; colors, both white; distance = 3″; p. = 317°; R. A. XXII h. 23.7 m.; D. — 0° 32′.

18.—The star Psi ($\psi'$) is an easy double even in a 2-inch instrument. Mag. of components, 4.5 and 8.5; A yellow, B blue; distance = 49″; p. = 312°; R. A. XXIII h. 10.7 m.; D.— 9° 38′.

20.—**Ă′-quil-a,** the Eagle (Maps pp. 57, 61, 53. N. H., R. A. XIX h. 20 m.; D. + 5°). The stars of Antinoüs are now included in Aquila. As this constellation lies in the Milky Way, it presents rich fields for all low-power instruments, though containing few easy doubles.

21.—Altair; a fine first-magnitude star, forming with Beta ($\beta$) and Gamma ($\gamma$) one of the clearest landmarks of the summer sky. R. A. XIX h. 45.9 m; D. + 8° 36′. I have called the linear figure formed by Alpha ($\alpha$), Gamma ($\gamma$), and Beta ($\beta$) the "shaft of Altair." Altair, next to Sirius and Pro′cyon, is the nearest first mag. star visible from northern latitudes, being at a "light-distance" of 14 years; see p. 9. Altair's annual proper motion is quite sensible, being 0″.65. It is yellowish white in color;—of the same general type as Sirius. It is approaching the earth at a velocity of over 1200 miles a minute.

22.—Very near to Lambda ($\lambda$) is a small double, not charted but easily found; marked as *15* in some maps; mag. of components, 5.5 and 7.5; A white, B lilac; distance = 34″.5; p. = 206°.6; R. A. XVIII h. 59.7 m.; D. — 4° 11′.

23.—A rich cluster marked M 11; R. A. XVIII h. 45.8 m.; D. — 6° 24′.

**Arc-tū′-rus,** see [41].

25.—**Ar′go Nā′-vis,** the Ship Argo. A large constellation, most of which is too far south for satisfactory observation in our latitudes. Some stars of Puppis appear low down in Maps pp. 45, 49; but for the whole constellation see S. H., R. A. IX h.; D. — 55°. Sometimes divided into four parts—Puppis, the stern; Vela, the sails; Carina, the keel; and Pyxis, the compass.

26.—The cluster marked M 46 is sometimes listed as 1564, or 2437. It is not difficult, forming an interesting object for small instruments. R. A. VII h. 37.2 m.; D. — 14° 35′.

27.—Can-ō′-pus, the leading star of this constellation, the Alpha ($\alpha$) of Argo (more specifically of Carina) is second only to Sirius [66] in brilliancy, but as it is very much more remote, being at a distance of, at least, three hundred light-years, it is probably many thousands of times greater in mass. It is a star of the same type as Procyon; though enormously larger in size. It has an annual proper motion of 0″.02 and a motion of 12 miles a second away from our system.

30.—**Ā′-ries,** the Ram (Maps pp. 61, 41, 55, 45, 43. N. H., R. A. II h. 30 m.; D. + 13°). An important constellation, lying in the Zodiac or pathway of the planets; see p. 80. This constellation, as will be seen by reference to the N. H. map, covers a far wider area than the region marked out by its three most conspicuous stars. According to one of the Greek myths, the mother of Phrixus and Helle gave to the former a ram having golden fleece. Fleeing from Hera, their step-mother, they reached the sea; and both attempting to cross on the ram's back, Helle was drowned (hence the Hellespont). Phrixus, after his escape, sacrificed the ram, and dedicated the fleece to Zeus. The fleece was carried away by Jason; but Zeus perpetuated the memory of the ram by giving it a place among the stars.

31.—Lambda ($\lambda$), a fine double star, mag. of components, 5 and 8; A white, B blue; distance $=38''$; p.$=45°$; R. A. I h. 52.4 m.; D.$+23°$ 7′.

32.—Gamma ($\gamma$)—the Arabic name is Mesartim—is an easy double star. It was discovered by Hooke in 1664; though it was not the first double star discovered, as is sometimes stated; see [401]. Mag. 4.7 and 4.8; A white, B pale gray; distance$=8''.6$; p.$=360°$; R. A. I h. 48 m.; D.$+18°$ 48′.

33.—The star *30* is also a double. It bears no symbol in the Key-Maps, but it will be found just to one side of a line from Alpha ($\alpha$) to Beta ($\beta$), continued a little over twice that distance. Mag. 6.6 and 7.4; A yellow, B gray; distance$=39''$; p.$=273°$; R. A. II h. 31.2 m.; D.$+24°$ 13′.

35.—**Au-rī′-ga;** the Charioteer. (Maps pp. 59, 47, 45, 41, 39. N. H., R. A. V h. 30 m.; D. + 42°.) This constellation, among the ancient Greeks, was connected with several myths. Among these may be mentioned the story that the group represents Erichthonius, son of Athena and Hephæstus, who was thus given a place among the stars because of his invention of the chariot. The name of the constellation appears in the Greek star lists of Eudoxus (4th century B.C.) and Aratus (3d century B.C.).

36.—Ca-pel′la, the leading star of the constellation, is accompanied by three fainter stars forming to the eye a small acute triangle. These, Epsilon ($\epsilon$), Eta ($\eta$), Zeta ($\zeta$), are called the Kids, Capella itself meaning, literally, the she-goat. The presence of "the kids" will always serve to distinguish Capella, in a clear sky, from the other bright stars. The group is situated so far to the northward that in its revolution about the Pole it is carried below the horizon, in our latitudes, for only a short period of time and so is almost always in our skies. Capella is brilliantly yellow or golden in color, and so much larger than our Sun that whereas Capella shines to us as a first magnitude star, the Sun at the same distance would appear as a star of only the fifth or sixth magnitude. Capella is a spectroscopic binary with a period of 104 days; see p. 117. It is at a light-distance of 49 years; and is receding from our system at a velocity of 18.6 miles a second. R. A. V h. 9.3 m.; D. $+45°$ 54′. Exact mag. 0.21.

38.—The small star marked *14* is an easy double, Mag. 5.1 and 7.2; A yellow, B blue; distance$=14''.5$; p.$=225°$. R. A. V h. 8.9 m.; D.$+32°$ 34′; the star is triple in large instruments.

**Bet′-el-geuze,** see [291].

40.—**Bō-ō′-tes,** the Herdsman. (Maps pp. 53, 49, 43, 47, 55, 57. N. H., R. A. XIV h. 30 m.; D. + 30°. A large and important constellation of the northern hemisphere, south of Ursa Major and west of Corona. The configuration of the Herdsman as it is usually suggested will be found in the text under the Night-Chart on p. 42. While not in the Zodiac, or pathway of the planets, Boötes is among the first recorded constellations.

41.—Arc-tū′-rus; a superb first-magnitude star, R. A. XIV h. 11.1 m.; D.$+19°$ 42′. Next to Sirius, Vega, and Capella, Arcturus is the brightest star visible from northern latitudes. Indeed it is rated in the *Revised Harvard Photometry* (1908) as of mag. 0.24,—nearly the same as Capella (0.21). The star is of a deep yellow color, possessing at times an almost reddish cast. Its motion in the line of sight (186.6 miles a minute) is toward us, but this velocity, as compared with many of the stars, is not high. The proper motion (see p. 138) of Arcturus is, however, unique among our brighter stars, making it an object of surpassing interest. This great star, at least 1000 times the size of our sun in volume, is rushing through space at a velocity of nearly 90 miles a second, or over 320,000 miles an hour. The direction, according to Newcomb, is southwest, or toward the constellation Virgo. We must remember, upon the other hand, that as Arcturus is so far distant from our system, light from the star requiring more than forty years in which to reach us, the high velocity of its motion has not altered its apparent position in the sky in 4000 years by much more than $2\frac{1}{2}°$, or 5 times the apparent diameter of the moon. No change in its position within a century could be detected except by the use of instruments of high precision. The advanced student should bear in mind that the above statement is based not on the parallax for the star of $0''.03$ for some time current, but on the corrected parallax of $0''.075$; see p. 139.

42.—Epsilon ($\epsilon$), a beautiful double star, but the beginner will find it difficult even with a three-inch instrument; mag. 5.1 and 2.7; A pale

orange, B green; distance $=2''.7$; p. $=330°$; R. A. XIV h. 40.6 m.; D. $+27° 30'$. Arabic name, Izar.

**43**.—Delta ($\delta$), double star; mag. 3.6 and 8; A pale yellow, B light blue; distance $= 105''$; p. $=79°$; R. A. XV h. 11.5 m.; D. $+33° 41'$.

**43b**.—Xi ($\xi$), double star; mag. 4.8 and 6.6; A yellow, B purple; distance $=3''$; p. $=200°$; R. A. XIV h. 46.8 m.; D. $+19° 31'$.

**44**.—Pi ($\pi$), double star; mag. 4.9 and 5.8; colors, both white; distance $=7''$; p. $=100°$; R. A. XIV h. 36 m.; D. $+16° 51'$.

**45**.—Kappa ($\kappa$), mag. 4.6 and 6.6; A white, B bluish; distance $=13''$; p. $=238°$; R. A. XIV h. 9.9 m.; D. $+52° 15'$; not far from Eta ($\eta$) of the Great Dipper.

**46**.—Iota ($\iota$) mag. 5 and 7.5; A pale yellow, B white; distance $=38''$; p. $=33°$; R. A. XIV h. 12.6 m.; D. $+51° 50'$.

**47**.—Mu ($\mu$), mag. 4.5 and 6.7; both white; distance $=108''$; p. $=171°.6$; R. A. XV h. 20.7 m.; D. $+37° 44'$.

**48.—Cam-el-o-par′-dus,** the Giraffe (Maps, all northern; N. H., R. A. V h.; D. $+ 70°$). A large but dull and unimportant constellation near the Pole.

**49**.—The star marked *19 H* is an easy and pretty double. Mag. 5 and 8.5; A yellow, B blue; distance $=16''$; p. $=10°$; R. A. V h. 6.1 m.; D. $+79° 7'$.

**50.—Can′-cer,** the Crab (Maps pp. 45, 49, 39, 51. R. A. VIII h. 25 m.; D. $+20°$). A small dull constellation, but of importance because lying in the Zodiac or pathway of the planets.

**52**.—A fine cluster called Præ′-se-pe, or the Beehive. The stars of this famous cluster are not so numerous as in many other clusters, but of sufficient magnitude to make a beautiful object in a small instrument. Galileo counted 36 soon after the making of his first telescope; later observers have counted over 300. R. A. VIII h. 34.7 m.; D. $+20°$.

**53**.—Iota ($\iota$) is a fine double, small but not difficult; mag. 4.2 and 6.6; A faint orange, B blue; distance $=31''$; p. $=307°$; R. A. VIII h. 40.6 m.; D. $+29° 8'$.

**54**.—Zeta ($\zeta$) is a remarkable triple star; only 2 components can be easily seen in small telescopes; mag. 5.6, 6, and 6.3; A B yellow, C orange; distance (AB–C) $=5''.5$; p. $=115°$; R. A. VIII h. 6.5 m.; D. $+17° 57'$. "One of the most remarkable multiple stars. The orbit of A and B has been well determined; they revolve about each other at a distance of less than $1''$, in a period of 60 years, and are accompanied by a third star, C, which revolves about the centre of gravity of all, in an opposite direction. From irregularities in the motion of C, it is concluded that it is a satellite of an invisible body around which it revolves in $17\frac{1}{2}$ years, describing an ellipse with a radius of about $\frac{1}{5}$ of a second, and that the two together circle around A and B in 600 or 700 years."—*Sir Robert Ball.*

**55**.—The cluster marked M 67 is composed of stars of mag. 9–12.5, surrounded by brighter stars in the form of a half-circle. The whole looks like a nebula in a small instrument, but a larger telescope shows the stellar formation of the group. R. A. VIII h. 46 m.; D. $+12° 10'$. This cluster is listed in some atlases as 1712; or 2682.

**60.—Cā′-nēs Ven-ăt′-i-cī,** the Hunting Dogs. (Maps, all northern except pp. 39, 59, also pp. 49, 53. N. H., R. A. XIII h.; D. $+40°$.) A small modern constellation, near handle of the Great Dipper, or Plough.

**61**.—Double star marked *12*; Alpha ($\alpha$) in some atlases. An easy object for very small instruments. This star was named by Halley "Cor Caroli" (the heart of Charles) in honor of the English monarch, Charles II. Mag. 2.9 and 5.4; A white, B blue; distance $=20''$; p. $=227°$; R. A. XII h. 51.4 m.; D. $+38° 52'$.

**62**.—The star marked *15* forms a wide double, easily divided by an opera-glass; the companion star is registered as *17;* mag. 6.2 and 6; distance $=290''$; p. $=297°$; R. A. XIII h. 5.1 m.; D. $+39° 4'$.

**63**.—The nebula M 51, listed sometimes as 1662, or 5194, is illustrated on p. 11; but it is beyond the range of small instruments. R. A. XIII h. 26 m.; D. $+47° 43'$.

**64**.—This cluster, marked M 3 (5272), is not so beautiful in structure as the preceding object, but is within range of small instruments. So seen, however, its appearance is nebulous, showing little brilliancy. R. A. XIII h. 38 m.; D. $+28° 53'$.

**65.—Cā′-nis Mā′-jor,** the Great Dog. (Maps, pp. 45, 41, 49. N. H., R. A. VII h.; D. $-20°$.) A fine constellation, southeast of Orion.

**66**.—Sĭ′-rius, the Alpha ($\alpha$) of this constellation, bluish white in color, is by far the brightest star in the heavens, being of magnitude $-1.6$, and having about 12 times the brilliancy of Aldebaran or about 13 times that of Pollux or Spica. Its intrinsic luminosity exceeds that of our Sun by 20 times. It is also the *nearest* of the stars visible to the unaided eye from the latitudes of Europe or N. America. It is at a light-distance of 8.7 years. The small star *61* in Cygnus was for a long time considered nearer than Sirius, but this is now known to be an error. Sirius represents, according to the spectroscope, a type of stars less advanced in development than our Sun, but older than the "Orion" stars; see [290]. Its proper motion is $1''.32$ a year, equivalent to 10.3 miles a second, or over 36,000 miles an hour. The distance of

the star is such, however, that—although it is relatively so near—it takes a century of time for it to move through a space on the celestial sphere equivalent to $\frac{1}{14}$ the apparent diameter of the moon. Its radial velocity (its velocity in the line of sight) is 300 miles a minute in the direction of our solar system. As Sirius is the leading star of the constellation, the Great Dog, it is sometimes called the Dog Star, and the days, July 25 to Sept. 5, when Sirius rises at nearly the same time as the Sun, are called "the dog days." And Homer's "Dog" was the star Sirius, always conspicuous in the night skies of autumn and winter.

> "The autumnal star, whose brilliant ray
> Shines eminent amid the depth of night,
> Whom men the dog-star of Orion call."

For Sirius was also frequently represented as the hunting dog of the Giant Hunter (see [290]). Sirius has a faint companion star, invisible except in large instruments. R. A. VI h. 40.7 m.; D. $-16°$ 35′.

**67.**—Star-cluster M 41, a fine spectacle in small instruments. R. A. VI h. 41.8 m.; D. $-20°$ 38′.

**68.**—Double star, Mu ($\mu$), mag. 5.2 and 8.9; A yellow, B gray; distance = 2″.5; p. = 340°; R. A. VI h. 51.5 m.; D. $-13°$ 55′. This star not included in Night Charts; but easily found by ref. to its Right Ascension and Declination in N. H. Map at close of book.

**70.—Cā′-nis Mī′-nor,** the Little Dog. (Maps pp. 45, 41, 49. N. H., R. A. VII h. 27 m.; D. +7°.) A small but ancient constellation, north of Canis Major, and containing one first magnitude star.

**71.**—Prō′-cy-on, "the precursor of the Dog"; or the star which precedes or goes before the Dog-Star, *i.e.* Sirius. Procyon is a star of the first magnitude and has, like Sirius, a faint companion. Like Sirius also it is one of the nearest of the brighter stars, being at a light-distance of 10 years. In its general nature or type it is midway between Sirius and our Sun. It has a proper motion of 1″.25. It is approaching our system at the rate of 150 miles a minute. R. A. VII h. 34.1 m.; D. +5° 29′.

**72.**—The little star marked *14* is a triple; mag. 5.5, 7, and 8; A white, B bluish, C blue; A–B, distance = 76″, p. = 66°; A – C, distance = 112″, p. = 153°; R. A. VII h. 53.2 m.; D. +2° 29′.

**Ca-nō′-pus,** see [27].

**Ca-pel′-la,** see [36.]

**75.—Căp-ri-cor′-nus,** the Sea-Goat. (Maps pp. 57, 61. N. H., R. A. XX h. 50 m.; D. – 18°.) A constellation of small stars, but important because lying in the Zodiac or pathway of the planets.

**76.**—The star Alpha ($\alpha$); name *Giedi;* a remarkable object, comprising at least six components. The two larger can be seen by a keen eye, unaided, or by a poor eye with assistance of opera-glass. Each of these is a triple; the four larger stars of the group are as follows: $\alpha^1$, mag. 3 and 9.5; $\alpha^2$, mag. 4 and 9; color of two chief stars, yellow; $\alpha^1$–$\alpha^2$, distance = 376″.1; p. = 291°; R. A. (of $\alpha^1$) XX h. 12.1 m.; D. – 12° 49′.

**77.**—Beta ($\beta$), an easy but pretty double; mag. 3.2 and 6.2; A orange, B blue; distance = 205″; p. = 267°. R. A. XX h. 15.4 m.; D. – 15° 6′. Arabic name, Dabih.

**78.**—Omicron ($o$) is also an easy double, though more difficult than the last; mag. 6.1 and 6.6; A white, B bluish; distance = 22″; p. = 240°; R. A. XX h. 24.2 m.; D. – 18° 55′.

**79.**—Pi ($\pi$), a double star; mag. 5.1 and 8.8; A pale yellow, B bluish; distance = 3″.5; p. = 146°; R. A. XX h. 21.6 m.; D. – 18° 32′.

**79b.**—Rho ($\rho$), a close double star; mag. 5 and 7.5. A white, B yellow; distance = 3″; p. = 173°; R. A. XX h. 23.2 m.; D. – 18° 9′. For location, see N. H., at the position just indicated.

**Ca-rī′-na,** see Argo Navis [25].

**80.—Cas-sio-pē′-ia.** (Maps, all northern, p. 39, etc. N. H., R. A. I h.; D. +60°.) A rich and interesting constellation of the northern sky, directly across the Pole from Ursa Major. In the mythical history of the group, Cassiopeia was the mother of Andromeda; see [1] in this Catalogue.

**81.**—Alpha ($\alpha$); a fine double, though the beginner may have difficulty just at first in detecting the smaller component. The primary star is variable, being 2.2 mag. at its brightest. Mag. of companion 9; A reddish, B blue; distance = 62″; p. = 280°. R. A. 0 h. 34.8 m.; D. +55° 59′. Arabic name, Schedir.

**82.**—The star Eta ($\eta$) is one of the most famous binaries. There is much difference among observers as to the colors. They are probably yellow and red, but the smaller star seems purple in small instruments. See p. 16. Mag. 3.7 and 7.6; distance = 5″.6; p. = 223°; R. A. 0 h. 43 m.; D. +57° 17′.

**83.**—Iota ($\iota$), a triple star; mag. 4.8, 7.1, and 8.1; A yellow, B blue, C blue; A–B, distance = 2″.2, p. = 254°; A–C, distance = 7″, p. = 110°. R. A. II h. 20.8 m.; D. +66° 57′. A 3-inch telescope will usually show only two components.

**Cas′-tor,** see [186].

**90.—Cen-tau′-rus,** the Centaur. (Maps pp. 49 and 53; and S. H., R. A. XIII h.; D. – 50°.) A large and brilliant constellation, visible, for the most part, only from latitudes near or south of the equator, but some of its northernmost stars can be seen in our evening skies of

June and July. Centaurus has two first-mag. stars, Alpha ($\alpha$) and Beta ($\beta$). The latter is not among the nearest of the very bright stars, its distance being 88 light-years; it has a small proper motion of 0".04 per year.

**91.**—Alpha ($\alpha$) is the nearest of the fixed stars, being at a light-distance of only 4.3 years. It is also a binary, the two components completing their period of revolution in a little over 81 years. The brighter component of the system, called $\alpha^2$, matches our Sun very nearly in size and in constitution. The proper motion of the pair is 3".66; they are approaching us at a velocity of 13.7 miles a second.

**100.—Cē′-phe-us.** (Maps, all northern; N. H., R. A. XXII h.; D.+73°.) A northern constellation, on the other side of the Pole from the Great Dipper. For the story of Cepheus, see Andromeda [1].

**101.**—The star Delta ($\delta$) is variable in magnitude; maximum, 3.7; minimum, 4.6; period 5d. 8h. 47m. 39s. It is also an interesting and easy double for very small instruments. Mag. of smaller star, 7.5; A deep yellow, B blue; distance=41"; p.=192°; R. A. XXII h. 25.4 m.; D.+57° 54′.

**102.**—Beta ($\beta$), a double star; mag. 3.3 and 8; A white, B blue; distance=13".5; p.=250°; R. A. XXI h. 27.4 m.; D.+70° 7′. Arabic name, Alphirk.

**103.**—The star Xi ($\xi$) is also an easy double, easier for a 2-inch telescope than the preceding. Mag. 4.4 and 6.5; colors, both bluish; distance =6"; p.=285°; R. A. XXII h. 0.9 m.; D.+ 64° 8′.

**104.**—The star Mu ($\mu$) was called by Sir William Herschel a "garnet" star, because of the intensity of its red color. In order to appreciate its peculiar hue, some white star, like the Alpha ($\alpha$) of Cepheus, should be compared with it at the time. R. A. XXI h. 40.4 m.; D.+58° 19′.

**110.—Cē′-tus,** the Whale. (Maps pp. 61, 41. N. H., R. A. I h. 35 m.; D.−10°.) A large constellation lying westward from Orion and south of Aries and Pisces; see [1].

**111.**—Alpha ($\alpha$), a second mag. star, yellow, with a blue star of the 5.5 mag. in same field; use low power. Not a true double, but an interesting object. R. A. II h. 57.1 m.; D. +3° 42′. Arabic name, Menkab.

**112.**—Gamma ($\gamma$), a fine double star for a 3-inch telescope; mag. 3.7 and 6.2; A yellow, B blue; distance=2".5; p.=290°; R. A. II h. 38.1 m.; D.+2° 49′.

**113.**—Omicron ($o$), one of the most remarkable of the variable stars; R. A. II h. 14.3 m.; D. − 3° 26′. Its name is Mira=the Wonderful. The variability of the star was discovered by Fabricius in 1596. "In 1779 Herschel saw the star when it was nearly as bright as Aldebaran, while 4 years later it was not visible even through his telescope. This means that at maximum it was at least 10,000 times as bright as at miminum. Ordinarily its maximum is much below that observed by Herschel and its minimum considerably above. . . . Three hundred years have only added to the mysteries associated with its behavior."—Moulton, *Introd. to Astronomy*, p. 531. See, also, p. 14 of this volume.

**114.**—Zeta ($\zeta$) optical dbl.; mag. 3.5 and 9; distance=185"; p.=41°; R. A. I h. 46.5 m; D.−10° 50′. Arabic name, Baten Kaitos.

**116.**—Double star, marked *66*; mag. 5.7 and 7.8. A pale yellow, B blue; distance=16".6; p.=230°; R. A. II h. 7.7 m.; D.−2° 52′.

**Co-lum′-ba**; see [125].

**120.—Cō′-ma Bĕr-e-nī′-ces,** Berenice's Hair. (Maps, pp. 49, 43, 53, 55; N. H., R. A., XII h. 40 m.; D. +24°.) A small but interesting group lying between Leo and Boötes. It is in the nature of a scattered cluster, not conspicuous to the naked eye but extremely pretty in opera-glass, in field-glass of large aperture, or in small telescope with low-power eyepiece. According to the ancient myth, Berenice—Queen of one of the Ptolemies of Egypt, 3d century B.C.—sacrificed her beautiful locks as a thank-offering for one of her husband's victories. Her hair, when shorn, was entrusted for keeping to one of Egypt's temples. From this it was stolen. The queen bitterly lamented the loss, and blamed the keepers of the shrine. They assured her, however, that Jove had placed her locks, for greater honor, in the skies; and they pointed out to her among the stars those strands and braids of twinkling light which we now know as "Coma Berenices." A very beautiful nebula, numbered in some lists as H. V. 24 (in others as 3106); is illustrated on p. 15. Unfortunately, it is not impressive in small instruments. R. A. XII h. 31.4 m.; D. + 26° 32′.

**121.**—The cluster marked M 53, noted in some atlases as 3453 or 5024, is also not brilliant in a small telescope. R.A. XIII h. 8 m.; D.+18° 42′.

**125.—Co-lum′-ba,** the Dove. (Maps pp. 41, 45. S. H., R. A. V h. 50 m.; D.−37°). A small constellation, located below Lepus and to the west of Canis Major. Its brightest star, Alpha ($\alpha$), mag. 2.8, is called Phact.

**130.—Cō-rō′na Bō-re-al′-is,** the Northern Crown. (Maps pp. 47, 59. N. H., R. A. XV. h. 35 m.; D.+30°). A constellation lying between Boötes and Hercules, forming a crown or chaplet of small stars; very beautiful as a group. The brightest star, Alpha ($\alpha$), mag. 2.3, is called Gemma, the Jewel [of the Crown].

**131.**—The star Zeta ($\zeta$) is a pretty double; mag. 6 and 5; A white, B blue; distance = 7″.5; p. = 305°. R. A. XV h. 35.6 m.; D. + 36° 58′.

**135.—Cor′-vus,** the Raven, or the Crow. (Maps pp. 49, 53. N. H., R. A., XII h. 20 m.; D. − 18°.) A small but clearly marked constellation lying between Hydra and Virgo. The two upper stars of Corvus point toward Spica, the first-magnitude star of Virgo, and form an interesting special group, see p. 26.

**136.**—The star Delta ($\delta$) is an easy but pretty double; mag. 3.1 and 8.4; A yellow, B purple; distance = 24″. 5; p. = 214°. R. A. XII h. 24.7 m.; D. − 15° 58′. Arabic name, Algorab.

**140.—Crā′-ter,** the Cup. (Maps pp. 49, 45, 53. N. H., R. A. XI h. 20 m.; D. − 15°.) A small constellation of small stars lying between Hydra and Corvus. The stars form the outline of a chalice or cup. The group contains few objects of telescopic interest.

**143.—Crux,** the Cross. (S. H., R. A. XII h. 30 m.; D. − 60°.) A small constellation near the south celestial Pole, remarkable for the "Southern Cross," a strikingly beautiful figure formed by its four brightest stars, one of which, Alpha ($\alpha$), is of the first magnitude; see p. 140. This star is at a distance of 59 light-years, and has a proper motion of 0″.06.

**145.—Cyg′-nus,** the Swan. (Maps pp. 39, 51, 57. N. H., R.A. XX h. 20 m.; D. + 41°.) Lying within one of the most impressive sections of the Milky Way, Cygnus contains many objects of interest and beauty. The stars Alpha ($\alpha$), Beta ($\beta$), Delta ($\delta$), Epsilon ($\epsilon$), and Gamma ($\gamma$) form the figure of a cross, and the group is often called the "Northern Cross" as distinguished from the "Southern Cross," noted above. The stars of the northern group, while not so brilliant as those of the southern, form an even clearer figure of the cross, because of the presence of a star, Gamma ($\gamma$), near the intersection of the beams. One of the most beautiful nebulæ of the constellation is shown on p. 8; but it is unfortunately beyond the range of the average telescope.

**146.**—The brightest star of the constellation, Alpha ($\alpha$), or Dĕn′-eb, is a star of the first magnitude (1.33), though one of the most remote among all the bright stars of the sky. It seems far less brilliant to us than Sirius, but its distance from us is so much greater that Newcomb estimates its actual luminosity as exceeding that of our Sun by at least a thousand times. It is distant from us more than 400 light-years; its parallax being imperceptible and its proper motion being also very small (see tables, pp. 138 and 139). In spite of its vast distance, we know from the spectroscope that it is a star of the same general type as Sirius, although probably more advanced in development. R. A. XX h. 38 m.; D. + 44° 55′.

**147.**—The star marked Beta ($\beta$) is given the name Al-bī′-re-o. It is one of the finest doubles for small instruments; mag. 3.2 and 5.4; A orange, B blue; distance = 34″.3; p. = 55°.7; R. A. XIX h. 26.7 m.; D. + 27° 45′. No physical connection has been detected; the star is probably not a binary.

**148.**—The star marked Omicron ($o$) has another quite near it, marked in many atlases $o^2$. They form an easy group for an opera-glass or field-glass. In a 2-inch or 3-inch telescope a companion to $o^2$ will be seen, and in a 6-inch instrument there appears still another component. This star, however, is very small, being rated as 11th or 12th magnitude. The three components visible in a small instrument are $o^1$, mag. 5; $o^2$, mag. 4; and the brighter companion of $o^2$, mag. 7. A and C are blue in color; B, or $o^2$, orange; A–B, distance = 337″.8; p. = 323°.7; A–C, distance = 106″.8; p. = 173°.5; R. A. of $o^2$, XX h. 10.5 m.; D. + 46° 26′.

**149.**—The star marked *32* is listed in some atlases as a double. This is an error, due to confusion with one of the components of the preceding object. But it is in the same interesting low-power field. R. A. XX h. 12.4 m.; D. + 47° 24′.

**150.**—This small object, marked *61*, is one of the most interesting doubles in the sky,—the first star whose distance from our sun was accurately measured. Bessel (1838) found a parallax of 0″.31, indicating a light-distance of 10½ years. This was later superseded in general estimation by Auwers' parallax of 0″.56, indicating a light-distance of 5.8 years, and making the star the nearest in the northern hemisphere. Statements to this effect appear in many current volumes of astronomy. But it has recently been determined that Bessel's original result was far nearer to the fact; the parallax of 0″.311 is now generally accepted. The light-distance of the star is thus 10.5 years; it is not so near as Sirius, but one of the nearest in our sky. See the table of star-distances, p. 139. The magnitudes of the components are 5.6 and 6.3; both yellow in color; (1905) distance = 22″.5; p. = 127°; R. A. XXI h. 2.4 m.; D. + 38° 15′.

**151.**—This star, which we mark Chi ($\chi$) is marked in some atlases as $\chi^2$, and the next star, *17*, is then marked $\chi^1$. The former star, which we mark simply $\chi$, has a distant companion, but it is chiefly remarkable as a long-period variable. For six months at a time it remains invisible to the unaided eye. Its "period" is 406 days. In about 3½ months it increases from its minimum brightness, mag. 13.5, to maximum. Its maximum, as in the case of the Omicron ($o$) of Cetus, is by no means uniform,

—ranging from mag. 6.5 to 4. Its color is a fine red except that its color-intensity decreases with its increasing brightness. R. A. XIX h. 46.7 m.; D.+32° 40′.

**152.**—The star marked *17*, sometimes called $\chi^1$, is an easy double for small instruments; mag. 5 and 8; A yellow, B blue; distance = 26″; p. = 73°; R. A. XIX h. 42.6 m.; D.+33° 30′.

**153.**—Mu ($\mu$) is a triple; two of the components being almost inseparable in a small instrument, and the third, and smaller, star more distant. Mag. 4.7, 6, and 6.7; A white, B blue, C blue; A–B, distance = 2″, p. = 125°; A–C, distance = 217″, p. = 61°; R. A. XXI h. 39.6 m.; D.+28° 18′.

**154.**—The star cluster M 39 is well worth finding. It is on a line from Beta ($\beta$) to Gamma ($\gamma$), continued about 14° onwards. R. A. XXI h. 28 m.; D.+48° 9′.

**155.—Del-phī′-nus,** the Dolphin. (Maps pp. 57, 61, 51. N. H., R. A. XX h. 40 m.; D.+12°.) A small but finely marked constellation lying south of Cygnus and east of Aquila.

**156.**—The star Alpha ($\alpha$) is a wide double; mag. 4 and 9.5; distance = 35″; p. = 278°; R. A. XX h. 35 m.; D.+15° 34′.

**157.**—The star Gamma ($\gamma$) is of special interest and beauty in a small instrument. Mag. 5.5 and 4.5; A yellow, B bluish-green; distance = 12″; p. = 274°; R. A. XX h. 42 m.; D.+15° 46′.

**Dĕn′-eb**, see [146].

**160.—Drā′-co,** the Dragon. (Maps, all northern, pp. 39, etc. N. H., R. A. XV h. 55 m.; D.+70°.)

**161.**—This star, Alpha ($\alpha$), is chiefly interesting because of its former position—4000 years ago—as the Pole Star. Its ancient name was Thū′-ban. The Pole is now near the star Polaris in Ursa Minor. See [406]. For explanations of such phenomena, see any one of the text-books on Astronomy noted on p. 145. R. A. XIV h. 1.7 m.; D.+64° 51′.

**162.**—Nu ($\nu$) is an easy but beautiful double, even for opera-glass and field-glass. Mag. of both components, 5; color, gray; distance = 61″.7; p. = 313°; R. A. XVII h. 30.2 m.; D.+55° 15′.

**163.**—Omicron ($o$) is another double. Mag. 4.8 and 7.6; A yellow, B lilac; distance = 32″; p. = 340°; R. A. XVIII h. 49.7 m.; D.+59° 16′.

**164.**—This star, Iota ($\iota$), is also a double though more difficult than the star just mentioned. Mag. 3.5 and 9; A orange, B yellow; distance = 254″.6; p. = 50°; R. A. XV h. 22.7 m.; D.+59° 19′.

**165.**—Gamma ($\gamma$) may possibly require a $3\frac{1}{2}$ or 4 inch telescope for its satisfactory observation, as the companion star is even smaller than in the preceding pair. Mag. 2.4 and 12; distance = 124″.7; p. = 116°; R. A. XVII h. 54.3 m.; D.+51° 30′. Arabic name, Etamin.

**166.**—Delta ($\delta$) is also a wide double and the companion is less difficult. Mag. 3 and 9.5; A yellow, B red; distance = 154″.7; p. = 27°.7; R. A. XIX h. 12.5 m.; D.+67° 29′.

**170.—Equū′-le-us,** the Little Horse (see N. H., R. A. XXI h. 10 m.; D.+5°), a small unimportant constellation lying between Delphinus and Pegasus. See the map of the N. H. at the close of this volume, at R. A. just indicated.

**175.—Ĕ-rĭd′-a-nus,** the River. (Maps pp. 41, 45. N. H. and S. H., R. A. III h. 40 m.; D.−25°.) A long line of stars starting near Rigel in Orion and flowing westward and southward toward Cetus and Fornax. Few telescopic objects of interest, but it contains one first-magnitude star, Alpha ($\alpha$), or Achernar (A′-ker-nar), visible only in far southern latitudes. See tables, pp. 139, 140.

**176.**—This star marked *w* is sometimes classified as *32*. The contrast in the colors of the components is peculiarly fine. Mag. 5 and 6.9; A yellow, B blue; distance = 6″.7; p. = 345°; R. A. III h. 49.3 m.; D.−3° 14′.

**177.**—Gamma ($\gamma$) is a good double for a 3-inch, though the companion—not to be confused with the small 6-mag. star in the same field—is rather small. Mag. 2.5 and 10; A yellow, B pale gray; distance = 51″.6; p. = 238°; R. A. III h. 53.4 m.; D.−13° 48′. Arabic name, Zaurak or Alhena.

**Fō′-mal-haut,** see [331].

**185.—Gĕm′-in-i,** the Twins. (Maps pp. 45, 41, 49, 39. N. H., R. A. VII h.; D.+22°.) One of the most interesting and important of the constellations. The two brightest stars, Castor and Pollux, even in prehistoric times, were suggestive of a pair—so near are they together and so conspicuous in brilliancy. Many have been the legends, even among savage peoples, in which these stars have been identified with heroic groups. But the most familiar to us is that which has given them the names of the warrior brothers, sons of Jupiter and Leda, whom Macaulay celebrates in his stirring poem, "The Battle of Lake Regillus."

**186.**—The star Castor, marked Alpha ($\alpha$) in all star maps, is a double star, a binary,—a fine object for a 2-inch or 3-inch telescope; mag. 2 and 2.9; colors, both greenish white; distance = 6″; p. = 225°; R. A. VII h. 28.2 m.; D.+32° 6′. It is also interesting to know that both components are spectroscopic binaries (see table of spectroscopic binaries on p. 143), and that at a distance of 73″ is another component, mag. 9, visible only in larger instruments. The parallax of Castor (0″.028) makes its distance about 116 light-years. Both of

the main components of Castor are "Sirian" stars, see [66.]

**187.**—Beta ($\beta$) or Pollux is a multiple star of at least 6 components, most of them at considerable distance from the primary and too faint for easy observation. Three may be seen in a telescope of 3 to $3\frac{1}{2}$ inches. Mag. 2, 9, and 9.5; A orange; A–F, distance = 242″, p. = 75°; A–E, distance = 219″, p. = 90°; R. A. VII h. 39.2 m.; D. +28° 16′. Pollux is brighter than Castor, although assigned the letter Beta ($\beta$). It is nearer, also; its distance is 51 light-years. It has a yearly proper motion of 0″.62. In its physical constitution it exactly resembles Arcturus [41]. It is slowly receding from our system.

**188.**—The fine star-cluster marked M 35—beautiful even in a good field-glass and visible in an opera-glass—is a fine object in a small telescope. Its existence, under good atmospheric conditions, can be detected with the unaided eye. R. A. VI h. 3 m.; D. +24° 21′.

**189.**—Kappa ($\kappa$), though not a large star, is an extremely pretty double in a 3-inch glass. Mag. 3.7 and 8; A orange, B pale blue; distance = 6″.4; p. = 235°; R. A. VII h. 38.4 m.; D. +24° 38′.

**190.**—Delta ($\delta$) is an easier double than the preceding. Mag. 3.7 and 8; A yellowish, B red; distance = 7″; p. = 210°; R. A. VII h. 14.2 m.; D. +22° 10′. Arabic name, Wesat.

**191.**—Epsilon ($\epsilon$) is also a double star. Mag. 3.2 and 9.5; A white, B blue; distance = 110″.6; p. = 94°; R. A. VI h. 37.8 m.; D. +25° 14′. Arabic name, Mebsuta.

**192.**—Lambda ($\lambda$) is a double star, mag. 4, unmarked by any letter in Key-Maps, just below Delta ($\delta$) and Zeta ($\zeta$) and forming a small triangle with them. It is a little difficult for any telescope smaller than a $3\frac{1}{4}$-inch, but is worth trying with a 3-inch on a clear night. Mag. 3.7 and 10; A white, B yellowish; distance = 10″; p. = 30°; R. A. VII h. 12.3 m.; D. +16° 43′.

**193.**—Zeta ($\zeta$) is itself a double star, and is an easy object even in a 2-inch instrument. Mag. of brighter star varies from 3.7 to 4.3; smaller component, about 7; A yellow, B blue; distance = 94″; p. = 350°; R. A. VI h. 58.2 m.; D. +20° 43′. Arabic name, Mekbuda.

**194.**—The small star Nu ($\nu$) is here inserted not only because it is a double, but because of its historic interest. It was near this star that Sir William Herschel discerned the object which he found to be an unknown planet, a discovery which—to human knowledge—doubled the diameter of the solar system. Uranus, as it came to be called, is over twice as far from the sun as Saturn, the remotest planet then known. The components of the little star Nu ($\nu$) are mag. 4 and 8; distance = 113″; p. = 330°; R. A. VI h. 23 m.; D. +20° 17′.

**200.—Her′-cū-lēs.** (Maps pp. 53, 47, 57, 59; N. H., R. A. XVII h. 20 m.; D. + 30°.) A large and important constellation lying between Lyra and Corona Borealis, and south of Ursa Major. The group is not easily recognized at first, but when once learned it becomes strikingly clear and interesting. The hero, as usually drawn, is supposed to be kneeling; his head at Alpha ($\alpha$), shoulders at Beta ($\beta$) and Delta ($\delta$), belt at Zeta ($\zeta$) and Epsilon ($\epsilon$); one knee at Rho ($\rho$) and one at Eta ($\eta$). In early lists, the constellation is often called the Kneeler. The easiest method for noting and identifying the group is indicated on p. 46.

**201.**—Alpha ($\alpha$) is a double star of especial charm and beauty. As the larger component is variable in brilliancy, the star will be found easier to divide at some seasons than at others. It can be divided, however, by a 3-inch, and sometimes by a 2-inch. Mag. (about) 3.5 and 5.4; A yellow, B blue; distance = 4″.8; p. = 113°; R. A. XVII h. 10.1 m.; D. +14° 30′. Arabic name, Ras Algethi.

**202.**—Delta ($\delta$) is an easier double than the above, if the air be clear and the night moonless. Mag. 3.2 and 8; A greenish, B bluish; distance = 15″; p. = 195°; R. A. XVII h. 10.9 m.; D. +24° 57′.

**203.**—Mu ($\mu$);—Mag. 3.5 and 8; A yellow, B blue; distance = 31″.5; p. = 245°; R. A. XVII h. 42.5 m.; D. +27° 47′.

**204.**—Rho ($\rho$) is a double, unusual in its coloring, the components being white and green. Mag. 4.5 and 5.5; distance = 4″; p. = 312°; R. A. XVII h. 20.2 m.; D. +37° 14′.

**205.**—This star, marked *95*, is also peculiar in the coloring of its components, one being red and the other green. It is not a difficult object, even for a good 2-inch, but it is small and not easy for the beginner to find. Mag. 5.1 and 5.2; distance = 6″; p. = 262°; R. A. XVII h. 57.2 m.; D. +21° 36′.

**206.**—The star-cluster M 13 is one of the most remarkable in the sky, comprising over 5000 stars. Sir Wm. Herschel's estimate of 14,000, though naturally suggested by the splendor of the central mass, was probably too large. Halley, who discovered it in 1714, reported it as one of six "nebulæ,"—all that were known in 1716. Before 50 years had passed, Messier had added nearly 100, and by 1830 the three Herschels (Sir William, Sir John, and Caroline) added more than 3000, counting both nebulæ and star-clusters. These were at first classified together,—for the nebulæ were generally regarded as star-clusters too distant or faint for the stars to be resolved by the telescope. We now know that the two classes of objects are distinct in character, see p. 19. M 13 is visible even in a 2-inch telescope, though its real interest and splendor cannot easily be gathered from an instrument less than

6 inches in aperture. R. A. XVI h. 39.1 m.; D. $+36°$ 39′.

**207.**—The star-cluster marked M 92 lies almost on a line between Pi ($\pi$) in Hercules and Beta ($\beta$) in the head of Draco. Easily visible, but with the appearance of a nebula, in small instruments. R. A. XVII h. 14 m.; D. $+43°$ 15′.

**208.**—Gamma ($\gamma$), a double star; mag. 3.8 and 8; A white, B lilac; distance $=40''.5$; p. $=240°$; R. A. XVI h. 17.5 m.; D. $+19°$ 23′.

**209.**—Kappa ($\kappa$), shown only in N. H., s. west of Gamma ($\gamma$). An easy double for very small instruments. Mag. 5.1 and 6.1; A yellow, B reddish; distance $=31''$; p. $=10°$; R. A. XVI h. 3.6 m.; D $+17°$ 19′.

**Hȳ′-a-des,** see [383].

**210.—Hȳ′-dra,** the Water-Snake. (Maps pp. 49, 45, 53. N. H., R. A. XI h.; D. $-17°$.) A constellation extending through more than a fourth of the southern sky, long and winding in form but not broad. Head south of Cancer, lying between Leo and Canis Minor; the tail reaching to Scorpius.

**211.**—Alpha ($\alpha$) is sometimes called Cor Hydræ, or the heart of Hydra; sometimes Alphard, the Solitary—as it shines brightly in a region of faint stars. It is a double, but difficult in anything less than a $3\frac{1}{2}$-inch. Mag. 2 and 10; A orange, B green; distance $=281''.2$; p. $=153°$; R. A. IX h. 22.7 m.; D. $-8°$ 14′.

**212.**—Epsilon ($\varepsilon$) is a multiple star of four components, but in a 3-inch or even in a $3\frac{1}{2}$-inch not more than two are likely to be seen. Mag. 3.5 and 6.8; A yellow, C blue; distance $=3''.5$; p. $=230°$; R. A. VIII h. 41.5 m.; D. $+6°$ 47′.

**220.—La-cer′-ta,** the Lizard. (Maps, all northern, except pp. 47 and 59. N. H., R. A. XXII h. 19 m.; D. $+45°$.) A small, inconspicuous constellation of little importance.

**221.**—The star marked *8* is a quadruple, but only two of the components are visible in instruments under 4 inches. Mag. 6, 6.5, 10, and 8.7; A white, B white, C greenish, D blue; A–B, distance $=22''.3$; p. $=186°$; R. A. XXII h. 31.4 m.; D. $+39°$ 7′.

**225.—Lē′o,** the Lion. (Maps pp. 45, 49, 53, 39, 51. N. H., R. A. X h. 25 m.; D. $+15°$.) One of the noblest of the constellations; between Cancer and Virgo; specially marked by the figure of the "sickle" formed by the stars Alpha ($\alpha$), Eta ($\eta$), Gamma ($\gamma$), Zeta ($\zeta$), Mu ($\mu$), and Epsilon ($\varepsilon$). The constellation lies in the Zodiac,—or track of the planets; and as it occupies a large part of the sky, the constellation-outline is often obscured or confused by one of the "wanderers."

**226.**—Alpha ($\alpha$) or Rĕg′-ū-lŭs, its brightest star, is a double, though rather difficult for a 3-inch. Mag. 1.8 and 7.6; A white, B purple; distance $=177''$; p. $=307°$; R. A. X h. 3 m.; D. $+12°$ 27′. Regulus is reckoned a first-magnitude star, although it is less than $\frac{1}{3}$ as bright as Vega [261], and only $\frac{1}{13}$ as bright as Sirius [66]. Its small parallax indicates a distance of more than 80 light-years. The spectroscope places it among the "Orion" class of stars, for which see [290].

**227.**—Gamma ($\gamma$) is one of the finest of all the double stars, and one of the most impressive binaries. Fortunately the distance between the components seems to be increasing, so that it is becoming still more available for small instruments. Mag. 2.6 and 3.8; A orange, B yellow; distance $=3''.6$; p. $=117°$; R. A. X h. 14.5 m.; D. $+20°$ 21′. Arabic name, Al Gieba.

**228.**—Tau ($\tau$) is a double so easy as to be separable by a good field-glass; mag. 5.4 and 7; distance $=90''$; p. $=170°$; R. A. XI h. 22.8 m.; D. $+3°$ 24′.

**229.**—Beta ($\beta$) or Deneb′-ola has a small neighbor star: too distant for real component; mag. 2.2 and 7; A bluish, B red; distance $=1134''$; p. $=201°$; R. A. XI h. 44 m.; D. $+15°$ 8′.

**235.—Lē′-o Mī-nor,** the Little Lion, literally the Lesser Lion. (Maps pp. 39, 43, 45, 49, 51. N. H., R. A. X h. 20 m.; D. $+34°$.) A small constellation of little importance, lying between Leo and Ursa Major.

**240.—Lē′-pus,** the Hare. (Maps pp. 41, 45. N. H., R. A. V h. 32 m.; D. $-20°$). A small constellation, just south of Orion.

**241.**—Alpha ($\alpha$) is a little difficult for a 3-inch, but easy for anything larger—if the eye be carefully on the lookout for the dull color of the companion. Mag. 2.6 and 9; A yellow, B gray; distance $=36''$; p. $=156°$; R. A. V h. 28. 3 m.; D. $-17°$ 54′. Arabic name, Arneb.

**242.**—Gamma ($\gamma$) is a wide but lovely pair, so easy as to be separable even by a good opera-glass. Mag. 3.8 and 6.4; A yellow, B pale green; distance $=95''$; p. $=350°$; R. A. V h. 40.3 m.; D. $-22°$ 29′.

**244.**—Beta ($\beta$), a rather difficult triple, except in instruments of $3\frac{1}{2}$ inches and over. Mag. 3, 10, and 11; A–B, distance $=3''$, p. $=300°$; A–C, distance $=66''$; p. $=146°$; R. A. V h. 24 m.; D. $-20°$ 50′. Arabic name, Nihal.

**245.—Lī′-bra,** the Scales, or the Balances. (Maps pp. 53, 49, 57. N. H., R. A. XV h. 8 m.; D. $-13°$.) A small constellation lying in the Zodiac or track of the moon and planets; between Virgo and Scorpius.

**246.**—Alpha ($\alpha$) is a wide double, easily divided by field-glass or opera-glass; mag. 2.9 and 5.3; A yellow, B gray; distance $=230''.8$; p. $=314°$; R. A. XIV h. 45.2 m.; D. $-15°$ 35′. Arabic name, Zuben el Genubi, the southern scale.

**247.**—Beta ($\beta$), not double in a small telescope, but the star is interesting because of its pale-green color. Mag. 2.7; R. A. XV h. 11.6 m.; D. $-9^\circ$ 1′. Arabic name, Zuben el Chamali.
**248.**—Iota ($\iota$) is a double but not easy even in a 3-inch. Mag. 5.5 and 9.5; A yellow, B purple; distance = 57″.5; p. = 110°.5. The smaller component is also double in a larger instrument. R. A. XV h. 6.5 m.; D. $-19^\circ$ 25′.

**250.**—**Lū′-pus,** the Wolf. (Maps pp. 52, 53. S. H., R. A. XV h. 20 m.; D. $-40^\circ$.) The reader should use the map of the S. H. for a view of the whole; the name not appearing in the smaller maps. A constellation lying directly south of Scorpius. Few of its stars ever rise sufficiently high in Europe or the United States for satisfactory observation.
**251.**—Xi ($\xi$) is an easy double, even in a 2-inch telescope. Mag. 5.4 and 5.7; distance = 11″; p. = 48°; R. A. XV h. 50.5 m.; D. $-33^\circ$ 40′.
**252.**—Eta ($\eta$) is also a double, though not quite so easy as the preceding. Mag. 3.6 and 7.8; distance = 15″; p. = 21°; R. A. XV h. 53.5 m.; D. $-38^\circ$ 7′.

**255.**—**Lynx,** the Lynx. (Maps pp. 39, 43, 51. N. H., R. A. VIII h.; D. $+45^\circ$.) An inconspicuous constellation, of little importance, lying between Ursa Major and Gemini.
**256.**—The star marked *19* is an easy and pretty triple. It is on a line from Polaris to Pollux, about 25° from the former, though the beginner will not find it readily. Mag. 6.5, 6, and 8; A white, B and C purple; A–B, distance = 14″.3, p. = 312°; A–C, d. = 215″, p. = 358°; R.A. VII h. 14.7 m.; D. $+55^\circ$ 28′.

**260.**—**Lȳ′-ra,** the Lyre. (Maps pp. 57, 59, 47, 51, 61. N. H., R. A. XVIII h. 30 m.; D. $+36^\circ$.) A constellation small in size but peculiarly rich in interest, lying between Cygnus, Draco, and Hercules.
**261.**—Alpha ($\alpha$) or Vēga—sometimes written Wega—is one of the brightest of the first-magnitude stars, bluish-white in color, and—according to the chemistry of the suns—in the vigor of stellar youth. Vega is of special interest to us for at least three reasons. First, it is in the general direction of this star that our solar system seems to move in the depths of space, though the exact point lies within the bounds of Hercules; see the note on p. 66. Secondly, we may remember that while Alpha ($\alpha$) in Ursa Minor is at present our Pole-star, being the nearest of the bright stars to the actual polar-point of the heavens, yet this polar-point is slowly shifting its position. We have already seen that 4000 years ago this point lay near Alpha ($\alpha$) in Draco. See [161]. In the time of Hipparchus (c. 136 B. C.) it was about 12° from our present Pole-star; it is now distant from it about $1\frac{1}{6}^\circ$; it will gradually come nearer to it and in the next century will be only 1′ of arc distant. This distance will then increase; at length it will approach Deneb—the brightest star in Cygnus—and then, about 12,000 years hence, it will be nearer to Vega than to Deneb, and Vega will be the Pole-star. Thirdly, it is of interest to know that Vega has a companion—rather difficult for a 3-inch, because of the extreme brilliancy of the primary, but available with a $3\frac{1}{2}$-inch or 4-inch telescope. Mag. 0.1 and 10; A bluish white, B deep blue; distance = 43″; p. = 140°; R. A. XVIII h. 33.6 m.; D. $+38^\circ$ 41′. The distance of Vega from our system is 35 light-years; its proper motion, 0″.35.
**262.**—Beta ($\beta$) is a variable star; its period, 12 days, 21 hours, 47 minutes, and ranging from mag. 4.1 to 3.4. It is also a triple star in a 3-inch instrument and an easy double for a 2-inch. Mag. of two of components, 6.7 and 9.2; A–B, distance = 46″, p. = 150°; A–C, distance = 67″.2, p. = 318°; R. A. XVIII h. 46.4 m.; D. $+33^\circ$ 15′. Arabic name, Sheliak.
**263.**—Epsilon ($\varepsilon$) is a famous double double. An opera-glass will show it double, a telescope of from 3 to $3\frac{1}{2}$ inches (depending somewhat on the eye of the observer and the quality of the object lens) will show each of these components to be itself a double. The beginner will need a high power, but the use of a power too high will make the field of view so small that both pairs cannot be kept in the field of the instrument. Each of these pairs is a binary, the two components revolving about a common centre of gravity; and the pairs in turn are probably also in slow revolution about a common centre of the whole system. We have perhaps a similar system in Castor (see [186]) though in that case the components of the two larger stars are too close together for separation in a telescope. In some atlases, Epsilon ($\varepsilon$) in Lyra is classified as two stars, $\varepsilon^1$ and $\varepsilon^2$, or $\varepsilon$ and *5*. The four components are as follows: $\varepsilon^1$, mag. 5 and 6; $\varepsilon^2$, mag. 5 and 5; $\varepsilon^1$ yellow, $\varepsilon^2$, white; $\varepsilon^1$–$\varepsilon^2$, distance = 207″; p. = 173°; R. A. XVIII h. 41 m.; D. $+39^\circ$ 34′.
**264.**—Eta ($\eta$) is a double star, though rather small for easy finding. Mag. 4.8 and 8; A blue, B violet; distance = 28″; p. = 84°; R. A. XIX h. 10.4 m.; D. $+38^\circ$ 58′.
**265.**—Zeta ($\zeta$), an easy and pretty double whether for a 2-inch or a 3-inch. Indeed a good field-glass, steadily held, will divide it. Mag. 4.3 and 5.9; A yellow, B greenish; distance = 44″; p. = 149°; R. A. XVIII h. 41.3 m.; D. $+37^\circ$ 30′.
**266.**—Delta ($\delta$) is also a wide double, an easy object for a field-glass or a very small telescope. Mag. 4.5 and 5.5. A orange, B white; distance = 750″; R. A. XVIII h. 50.2 m.; D. $+36^\circ$ 51′.
**267.**—Between Gamma ($\gamma$) and Beta ($\beta$), and

somewhat nearer the latter star, lies M 57, the famous "Ring Nebula," interesting but not impressive in a small telescope. R. A. XVIII h. 49 m.; D. $+32°$ $53'$.

**Mī'-ra,** see [113].

**Mī'-zar,** see [401].

270.—**Mŏn-ŏ'-cĕr-ŏs,** the Unicorn. (Maps pp. 45, 49. N. H., R. A. VII h. 20 m.; D. $-4°$.) A large constellation of inconspicuous stars, lying between Orion and Hydra.

271.—The star Beta ($\beta$), sometimes marked *11*, is a fine triple. Mag. 4.7, 5.2, and 5.6. White; A–B, distance $= 7''.5$, p. $= 133°$; A–C, distance $= 3''.1$, p. $= 108°$; R. A. VI h. 24 m.; D. $-6°$ $58'$.

272.—Epsilon ($\epsilon$) is an easy double; the field of stars in which it lies is especially fine. Mag. 4.5 and 6.5; A yellow, B blue; distance $= 14''$; p. $= 26°$; R. A. VI h. 18.5 m.; D. $+4°$ $39'$.

273.—Almost on a line between Epsilon ($\epsilon$) and Delta ($\delta$) will be found a star-cluster, marked in some atlases 2301, or 1465. It is in three branches. R. A. VI h. 47 m.; D. $+0°$ $35'$.

274.—Not far from Epsilon ($\epsilon$) is a peculiarly beautiful cluster. It is marked in some atlases 1424, or 2244. Its general direction from the star may be noted in the Night Charts of the constellation. It is a good object even for opera-glass or field-glass. R. A. VI h. 27 m.; D. $+4°$ $56'$.

275.—Star-cluster 1637 or 2548, fairly large, and crowded with ninth-mag. stars. R. A. VIII h. 9 m.; D. $-5°$ $30'$.

285.—**Ō-phi-ū'-chus,** the Serpent-Bearer. (Maps pp. 53, 57. N. H., R. A. XVII h. 20 m.; D. $-5°$.) A large constellation, lying southward from Hercules and northward from Scorpius. Its outline is peculiarly difficult to the beginner and its study may, therefore, well wait until other groups are learned. In studying it, remember that being able "to see the man and the serpent" is of far less importance than the ability to recognize the constellation itself as a definite group of stars. First note that the Alpha ($\alpha$) of this group is brighter than the Alpha ($\alpha$) of Hercules, quite near it. Take then this brighter star as the apex of the triangle, Alpha ($\alpha$), Beta ($\beta$), Kappa ($\kappa$). See the map on p. 53. Then trace the right-angled triangle, Beta ($\beta$), Kappa ($\kappa$), Epsilon ($\epsilon$). On a clear night this triangle is made more evident by noting that at each corner is a pair—Beta ($\beta$) and Gamma ($\gamma$) at one corner; Kappa ($\kappa$) and Iota ($\iota$) at the next, Epsilon ($\epsilon$) and Delta ($\delta$) at the third. Having learned this much of the group, the irregular line of stars from Epsilon ($\epsilon$) to Theta ($\theta$) is not difficult. Serpens, the Serpent [365], divided by the above figure, lies in two parts—the head to the west or to the right, the tail to the east, or left; and the Serpent-Bearer, with head at Alpha ($\alpha$), and shoulders at Beta ($\beta$) and Kappa ($\kappa$), stands astride the serpent, with left hand grasping its coil at Epsilon ($\epsilon$), one knee at Zeta ($\zeta$) and one at Eta ($\eta$). The right hand of the figure also grasps the serpent at Nu ($\nu$) in Serpens. See also [365]. Ophiuchus contains little of telescopic interest in a small instrument. The Arabic name of Alpha ($\alpha$) is Ras Alhague.

286.—The star marked *67* is an easy double even for a 2-inch. This and *70* are in an interesting field. Mag. 4 and 8; A yellowish, B purple; distance $= 54''.5$; p. $= 144°$; R. A. XVII h. 55.6 m.; D. $+2°$ $56'$.

287.—The star marked *70* is also a double, though a little more difficult than the preceding. Rapidly changing binary: measures for 1911. Mag. 4.3 and 6; A yellow, B reddish; distance $= 3''.47$; p. $= 148°$; R. A. XVIII h. 0.4 m.; D. $+2°$ $31'$.

288.—In the region of Beta ($\beta$), slightly to the northeast, is a very pretty cluster of 8th magnitude stars, unmarked in many of the atlases. Its place is indicated in N. H., R. A. XVII h. 40 m.; D. $+5°$ $40'$.

289.—A fine cluster marked in the Key-Maps as M 12. It lies on a line between Epsilon ($\epsilon$) and Beta ($\beta$); forming almost a right angle with Epsilon ($\epsilon$) and Lambda ($\lambda$). R. A. XVI h. 42 m.; D. $-1°$ $45'$.

290.—**Ō-rī'-on.** (Maps pp. 41, 45, 49. N. H., R. A. V h. 26 m.; D. $0°$.) On the whole the richest and most impressive of the constellations. The mythology of the constellation has taken so many forms that it is impossible to say which should have the precedence in age or interest. The group has always, however, represented a Giant Hunter. As sings Longfellow in his "Occultation of Orion,"—

> "Begirt with many a blazing star
> Stood the great giant Algebar,
> Orion, hunter of the beast!
> His sword hung gleaming by his side,
> And on his arm the lion's hide
> Scattered across the midnight air
> The golden radiance of its hair."

According to one legend, the Giant Hunter was the companion of the Huntress Diana, who loved him and whom he desired to wed. Her brother, Apollo, was so opposed to their union that he caused the death of Orion by a scorpion's sting. At Diana's intercession, Orion was not only given a place among the stars, but was placed opposite to Scorpius (Scorpius always sets as Orion rises), that he might never again be troubled by the offensive reptile.

The spectrum of most of the brighter Orion stars shows—despite the wide area covered—that they are much alike in physical constitution and that they have, possibly, some physical connection—as if forming a loose but common

cluster. Betelgeuze [291] should probably be regarded as an exception. Epsilon ($\varepsilon$) and Gamma ($\gamma$), Alnilam and Bellatrix, are characteristic specimens. Stars which, under spectrum analysis, show that they are of the "Orion type" are in the earlier stages of stellar development. They are extremely remote, most of them being at a light-distance of over 300 years, and—as is usual with the most distant stars—revealing a very small proper motion.

**291.**—Alpha ($\alpha$), or Bĕt′-el-geuze, is the only marked "variable" among the first-magnitude stars, shining sometimes as a star of mag. 1.4 and sometimes as mag. 0.9 (period about 200 days), but never falling below the full first-magnitude standard. A singularly beautiful object, variously estimated as "red," a "rich topaz," a "reddish orange," etc., in color. In order to appreciate the real contrasts in star-color, the beginner should look alternately with his instrument at this star and at Rigel, or Beta ($\beta$), of the same group. Betelgeuze is a spectroscopic binary, see p. 143. In spite of its brilliancy, it is a distant star, its light taking more than a hundred years to reach us. It has a small proper motion, 0″.03. It is not of the "Orion" type, but represents a later stage of development. R. A. V h. 49.8 m.; D. $+7°$ 23′.

**292.**—Beta ($\beta$) or Rigel—pronounced Ree′-gel—is bluish-white in color, of intense brilliancy and beauty. It is one of the most remote of the brighter stars, being at a light-distance of at least 450 years. It is a double, separable, by a well-trained eye, under perfect conditions of light and air, with a 2¼-inch telescope. The companion is not especially close; but so great is the brilliancy of the larger component that, in order to see the smaller, the beginner will usually need a telescope of 3¼ or 3½ inches in aperture. Mag. 0.34 and 6.7; A pale yellow, B blue; distance = 9″.5; p. = 200°; R. A. V h. 9.7 m.; D. $-8°$ 19′. Rigel has no observable proper motion, nor motion toward or from us. In constitution it is conspicuously of the "Orion" type, tending toward the Sirian.

**293.**—Delta ($\delta$), the "top star of the belt," is an easy and beautiful object in a 2-inch instrument; indeed, after the eye has had a little experience, the star can be divided even by a good 10x field-glass. Mag. 2.5 and 6.9; A white, B violet; distance = 53″; p. = 360°; R. A. V h. 26.9 m.; D. $-0°$ 22′. Arabic name, Mintaka.

**294.**—The star Theta ($\theta$) is a quadruple, lying within the field of the great Orion-nebula. See illustration, p. 21. The nebula itself is one of the few that may be seen with satisfaction in small instruments. Naturally enough, the larger the telescope the better the view, but even an opera-glass will indicate its existence. It shows to best advantage on a clear night when there is little or no moonlight. The nebula is composed of luminous gases, and its distance from us, and the immensity of its proportions, are so great that we can form no conception of them except in vague and general terms. It is probably at a light distance of more than 250 years, and its bounds probably exceed by many thousand times the area inclosed by the orbit of Neptune, our outermost planet. It seems to be receding from us in space at the rate of about 600 miles a minute. The star Theta ($\theta$) is itself of great charm and interest even in a 2-inch telescope. The four components form what is called a "trapezium," an irregular quadrilateral. Mag. 6.8, 7.9, 5.4, and 6.9; A white, B lilac, C garnet, D reddish; A–B, distance = 8″.7, p. = 32°; A–C, distance = 13″, p. = 132°; A–D, distance = 21″, p. = 95°; R. A. V h., 30.4 m.; D. $-5°$ 27′. Large telescopes show the existence of several fainter stars in the trapezium group.

**295.**—The star marked *m* is an easy double for small instruments. Mag 5 and 5.1; distance = 32″; p. = 28°; R. A. V h. 17.6 m.; D. $+3°$ 27′.

**296.**—Zeta ($\zeta$), the third star of the belt, is a triple, but it is not an easy object for an instrument smaller than a 3¼-inch. Mag. 2, 4.2, and 10; A yellow, B purple, C gray; A–B, distance = 2″.8, p. = 158°; A–C, distance = 57″, p. = 9°; R. A. V h. 35.7 m.; D. $-2°$ 0′.

**297.**—Iota ($\iota$) is the third-magnitude star just below Theta ($\theta$) in the Key-Maps. It bears no symbol, because the map here is crowded, but its identity—together with the smaller star to the right—will be evident. Iota ($\iota$) is a triple, but will appear only a double in a telescope of 3-inches or under. It is not easy with a 2-inch. The beginner will find the smaller stars in this immediate region somewhat confusing, at the first, but will soon learn to distinguish them. Mag. 3, 7, and 11; A white, B pale blue, C red; A–B, distance = 11″.5, p. = 142°; A–C, distance = 49″, p. = 103°; R. A. V h. 30.5 m.; D. $-5°$ 59′. Just to the west (or right, as observer faces south) of Iota ($\iota$) is a smaller star, a pretty double, also not marked in our charts because of the danger of overcrowding. It is listed here, however, because it is so easy and pretty as to be noted by almost any observer of the region round the great nebula. The technical name for the star is Struve 747. It is a good object for a 2-inch telescope or even for a 10x field-glass. Mag. 4.7 and 5.6; distance = 36″; p. = 223°; R. A. V h. 30.1 m.; D. $-6°$ 5′.

**299.**—Sigma ($\sigma$) is one of the most remarkable of the multiple stars, a quintuple, three of its components being visible in a 3-inch, or even in a 2-inch, telescope. Mag. 3.9, 5, 9.5, 6.8, 6.3. A–B, distance = 0″.3, p. = 330°; AB–C, distance = 11″.3, p. = 237°; AB–D, distance = 12″.8, p. = 83°; AB–E, distance = 41″.4, p. = 61°;

E–D, distance = 30″.1, p. = 231°; R. A. V h. 33.7 m.; D. −2° 39′.

300.—Lambda (λ), the star that marks Orion's head, is a triple; two of its components visible in a 3-inch. Mag. 3.7, 5.6, and 10; A yellow, B purplish; A–B, distance = 4″.5, p. = 43°; A–C, distance = 28″.6, p. = 183°; R. A. V h. 29.6 m.; D. +9° 52′.

301.—**Pĕg′-a-sus,** the Winged Horse. (Maps pp. 61, 41, 55, 43. N. H., R. A. XXII h. 50 m.; D. +20°.) A large constellation, of marked general interest because of the "great square" for which it is conspicuous. This is formed by its stars Alpha (α) or Markab, Beta (β) or Scheat, Gamma (γ) or Algenib, and the Alpha (α) of Andromeda. But it has few objects for telescopic study.

When the head of Medusa was struck off by Perseus, Pegasus—the Winged Horse—sprang from the blood of the Gorgon. Pegasus was afterward caught by Bellerophon with the golden bridle, gift of Athena. The hero then, after his triumph over the Chimæra, attempted to ascend to the heavens on his winged horse. He fell to the earth; but Pegasus, ascending, was given a place in the stars. For the connection (?) of Pegasus with Perseus and Andromeda, see [1]. But this connection belongs to a much later legend.

302.—Epsilon (ε) is a wide double star. Mag. 2.5 and 8.5; A yellow, B violet; distance = 138″; p. = 323°; R. A. XXI h. 39.3 m.; D. +9° 25′. Arabic name, Enif.

303.—The cluster marked M 15 is globular in form, looking somewhat like a nebulous oval in a small telescope; but revealing its star-structure in larger instruments. R. A. XXI h. 25.1 m.; D. +11° 44′.

304.—The little star Pi (π) has near it another marked in some atlases as $\pi^2$. The pair make a pretty object for a 2-inch, or for a field-glass. The stars are of mags. 4.4 and 5.7; R. A. XXII h. 5.5 m.; D. + 32° 41′.

305.—**Per′-se-us.** (Maps pp. 59, 55, 43, 47. N. H., R. A. III h. 20 m.; D. +45°.) A rich and brilliant constellation of the northern sky, somewhat irregular in form, lying between Auriga and Cassiopeia. The breast of the hero is supposed to be at Alpha (α), the head at Gamma (γ), one hand grasping his sword at the cluster $h$–$\chi$, and the other holding the head of Medusa at Beta (β). One knee is at Mu (μ), the other at Xi (ξ). For the story of Perseus, see [1], in connection with Andromeda.

306.—The star Alpha (α) lies directly within the Milky Way and is the centre of a brilliant field of stars. There are few finer spectacles, whether for the opera-glass, the field-glass, or the small telescope. R. A. III h. 17.2 m.; D. +49° 30′. Arabic name, Algenib or Marfak.

307.—Beta (β) is the famous variable, Algol, discussed on p. 14. R. A. III h. 1.7 m.; D. +40° 34′.

308.—The star Eta (η) is a double for a 3-inch. Mag. 3.9 and 8.5; A orange, B blue; distance = 28″; p. = 300°; R. A. II h. 43.4 m.; D. +55° 29′.

309.—The double star-cluster $h$–$\chi$ is one of the very finest in the sky, and is peculiarly beautiful in small instruments. The use of high magnifying powers will necessarily reduce the size of the field and the impressiveness of the spectacle. On a 3-inch the best eyepiece to use is one from 25x to 40x; on a 2-inch telescope, use 15x to 25x. On telescopes of other apertures use powers proportionately low. See the illustration, p. 5. R. A. II h. 14 m.; D. +56° 40′.

310.—Zeta (ζ) is a quadruple star; though a small instrument will show only two of the components. It is not easy for any telescope smaller than a 3¼. Mag. 3, 9.3, 10, and 11; A white, B and C blue. A–B, distance = 12″.8; p. = 207°; R. A. III h. 47.8 m.; D. +31° 35′.

311.—A fine star-cluster marked M 34, a good object for a 2-inch or 3-inch telescope, lies on a line from Gamma (γ) in Andromeda to Beta (β) in Perseus. R. A. II h. 36 m.; D. +42° 21.′

320.—**Pis′-cēs,** the Fishes. (Maps pp. 61, 41. N. H., R. A. 0 h. 30 m.; D. +15°.) A large constellation, lying in the track of the planets, between Aquarius and Aries. It is important because of its position, but it has few brilliant objects of telescopic interest.

321.—Alpha (α) is a fine double, but the components are so near each other as to be a little difficult with a 3-inch, and the distance seems to be decreasing. It is worth trying with a 3-inch, however; and a little experience, with good atmospheric conditions, will bring success. Mag. 4.3 and 5.2; A pale green, B blue; distance = 2″.5; p. = 320°; R. A. I h. 56.9 m.; D. + 2° 17′. Arabic name, El Rischa.

322.—Zeta (ζ) is an easy and pretty double star lying between Mu (μ) and Epsilon (ε). Mag. 5.6 and 6.5; A white, B grayish; distance = 24″; p. = 64°; R. A. I h. 8.5 m.; D. +7° 3′.

323.—Psi (ψ); marked $\psi^1$ in some atlases; an easy double. Mag. 5.6 and 5.8; both white; distance = 30″; p. = 160°; R. A. I h. 0.4 m.; D. +20° 56′.

330.—**Pis′-cis Aus-trī′-nus,** the Southern Fish. (Map p. 61. N. H., R. A. XXII h. 15 m.; D. −30°.) Not to be confused with Pisces, the Fishes; see above. A southern constellation chiefly characterized by the fine first-magnitude star Fō′-mal-haut (Fō′-mal-ō), which is supposed to mark the Fish's mouth. It lies south of Aquarius, and is a conspicuous object in the southern sky during the early evenings of autumn.

**331.**—Fō′-mal-haut (pronounced Fō′-mal-ō), to which reference has just been made, has a distant companion; dif. in R. A. 4.8 sec.; p. = 195°; mag. of the two components 1.3 and 9.5. Many astronomers would rightly contend that stars so far apart should not be classified as a true double. But Smyth does well to list it because of the general interest in all first-magnitude stars. The dull blue companion is by no means easy. R. A. XXII h. 52.1 m.; D. −30° 9′. Distance of Fomalhaut is 24 light-years; proper motion, 0″.37. In general type, it resembles Sirius [66].

**332.**—Beta (β) is an interesting double star, even in a 2-inch instrument. Mag. 4.4 and 7.8; distance = 30″; p. = 172°; R. A. XXII h. 25.9 m.; D. −32° 52′.

**333.**—Gamma (γ) is a double also but not so easy as the preceding. Mag. 4.5 and 8.8; distance = 4″; p. = 270°; R. A. XXII h. 47 m.; D. −33° 24′.

**Plei′-a-des,** see [382].

**Pō-lar′-is,** see [406].

**Pŏl′-lux,** see [187].

**Præ′-se-pe,** see [52].

**Prō′-cy-on,** see [71].

**Pup′-pis; Pyx′-is,** see [25].

**Rĕg′-ū-lus,** see [226].

**Rī′-gel,** see [292].

**335.—Sa-gĭt′-ta;** the Arrow. (Maps pp. 57, 61, 51; N. H., R. A. XIX h. 40 m.; D. +18°.) A small constellation lying in the Milky Way slightly to the north of Altair. It is of interest to the eye because it really looks like an arrow. Between Delta (δ) and Gamma (γ), and slightly below a line connecting them, there lies a small cluster marked in some atlases M 71 and in others 4520, or 6838. It is not impressive in a small instrument. R. A. XIX h. 49.3 m.; D. +18° 31′.

**340.—Sa-git-tā′-rius,** the Archer. (Maps pp. 57, 53, 61; N. H., R. A. XIX h. 15 m.; D. −25°.) A large constellation, in the track of the planets, between Capricornus and Scorpius. The constellation is not rich in double stars, but it presents a fine spectacle to the unaided eye and it lies in a region crowded with nebulæ and star-clusters of great beauty.

**341.**—The object marked M 8 is, under good atmospheric conditions, visible to the naked eye. It can be found by projecting a line from the star Phi (φ) to Lambda (λ) and continuing it an equal distance. The cluster is just below the termination of the line. It is a cluster superposed upon a fine nebula. See, however, the illustration on p. 115. R. A. XVII h. 57.7 m.; D. −24° 22′.

**342.**—Just north of the preceding object and more nearly at the termination of the line just suggested is the rich nebula marked M 20. It is sometimes called the "Trifid" nebula, because of its triple form. R. A. XVII h. 56.3 m.; D. −23° 2′.

**343.**—The cluster M 22 lies on a line drawn from Tau (τ) to Sigma (σ), continued about half as far again. It is a beautiful and impressive object. R. A. XVIII h. 30.3 m.; D. −23° 58′.

**344.**—This, marked M 17, is the famous Omega nebula, thus called by reason of its supposed resemblance to that Greek letter. It is irregular in form; a fine object. R. A. XVIII h. 14.9 m.; D.—16° 13′.

**345.**—This cluster, M 24, is not far from the above, a little to the north or just over it and to the left—as we face southward. R. A. XVIII h. 13 m.; D. −18° 28′.

**346.**—The multiple star Mu (μ), omitted from the Night Chart in order to avoid over-crowding, is indicated in N. H. It is a fourth-magnitude star lying almost midway between M 8 and M 24, a little nearer the latter. While the star is a quintuple, a 3-inch instrument will probably show but two of the components to the average eye. Mag. 3.5 and 9.5; distance = 48″.3; p. = 312°; R. A. XVIII h. 7.8 m.; D. −21° 5′.

**350.—Scorp′-i-us,** the Scorpion. (Maps pp. 53, 57; N. H., R. A. XVI h. 35 m.; D. −30°.) The name of the group is sometimes written Scorpio. It is a large and important constellation lying in the track of the planets, between Libra and Sagittarius. It presents an impressive field of stars, beautifully grouped and bearing much likeness to the object for which it has been named. Indeed it looks more like the real scorpion of the tropics than do some of the weird illustrations of it presented in our mythological star-maps.

**351.**—Alpha (α), or Ant-ā′-rēs, is one of the finest of the first-magnitude stars, somewhat varying in hue, but predominantly red. Hence its name Antares, opposed to, or rivalling, Mars,—Mars being of course the red planet. It was also called *Καρδία Σκορπίου* by the Greeks, *Cor Scorpionis* by the Latins, and *Kalb-al-'akrab*, by the Arabs,—all meaning the Scorpion's Heart. It possesses a small companion star, but the components are not easily separable except in a telescope of 3½-inches or over. Some observers claim to have seen the small star with a 3-inch, under fine atmospheric conditions, but the average eye will require a larger instrument. Mag. 1.2 and 7; A red, B blue; distance = 3″; p. = 275°; R. A. XVI h. 23.3 m.; D. −26° 13′. It is also a spectroscopic binary; p. 117, col. 2. Its distance is over a hundred light-years, but it is drawing nearer

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**HALLEY'S COMET, MAY 26, 1910**

*From a photograph taken at the Lick Observatory*

## VIII. Star Distances, Star Motions, Magnitudes, etc.

We have seen, p. 9, that the stars are at such vast distances from us that the unit of measurement is the "light-year,"—the distance traversed by light, at a velocity of over 186,320 miles a second, in a year of time. To find the distance of a star, the astronomer must determine its parallax—the angle subtended at the star by the radius of the earth's orbit. Although this base line represents the distance between Earth and Sun, or approximately 93,000,000 miles, there are multitudes of stars which show no parallax. Indeed they are so remote that a line representing the whole diameter of the orbit, or over 185,000,000 miles, assumes but the aspect of a vanishing point in the perspective of the star's distance. Bessel, a great German astronomer, obtained (1838) the first satisfactory measure of a parallax,—that of the small star known as *61*, in Cygnus. It was long thought to be the nearest visible to the unaided eye from our latitudes, but this position now belongs to Sirius. A *telescopic* star, "Lalande 21,185," is the nearest known in the northern skies.

In the following table the parallax of the stars is indicated in the column marked P. These parallaxes have been obtained by different astronomers, but they are here presented from the list of Kapteyn and Weersma, *Groningen*, 1910; Kapteyn being the most generally accepted living authority on the general problem of stellar distances. They are not all entitled to equal weight. I have, therefore, ranked them in the col. marked F according to the degree of *finality* which should probably be accorded them. For these estimates of finality K. and W. are not responsible. A parallax classed as A is probably accurate within 0″.02; a parallax classed as B is probably accurate within 0″.03 or 0″.04; and C, within 0″.05 or 0.″06. In the column marked D is noted the *distance* of the star in light-years, based on the parallax given. The greater the distance, the more uncertain become all the conditions involved, so that the figures for stars at a light-distance exceeding 100 years become necessarily more like approximations than like rigid calculations. In many cases, however, these approximations are as likely to be underestimates as overestimates. Where a negative parallax is indicated (by the minus sign preceding) the star is too far distant to be measured at all, and the light-distance can only be roughly stated as *over* 500 years. At the foot of the table are the figures for a few stars invisible to the naked eye. The velocity of "the runaway star," Groombridge 1830 (a faint star in Ursa Major), is over 200 miles a second, or over 720,000 miles an hour. No explanation of such phenomena is yet at hand. Most of the stars show traces of association into groups, different groups betraying a common drift.

We now know that the stars, instead of being really "fixed," have motions of their own, relative to our own position in space. The motions of a star may be defined, in the terms of its annual displacement on the celestial sphere, in seconds of arc. This is usually called its proper motion, see the column marked P. M. Or when expressed as a velocity in miles per second it has been called the star's "Cross Motion." This is indicated in the column marked C. M. To secure the velocity per minute multiply of course by 60. But the stars have another motion also—a motion that represents no displacement on the celestial sphere, for it is *in the line of sight*. This linear motion is indicated in the terms of velocity in miles per second in the column R. V. (=radial velocity). When the star is

approaching our system, decreasing the distance at the velocity indicated, the minus sign accompanies the figure; where the star is receding from us and the distance is increasing, the indicated velocity is preceded by the sign plus (+). Stars enclosed in brackets [ ] are visible only from extreme southern latitudes.

TABLE A. STAR DISTANCES AND STAR MOTIONS

| Mag. | The Star | P. | D. | F. | P. M. | C. M. | R. V. |
|---|---|---|---|---|---|---|---|
| 0.1 | [Alpha (α) of Centaurus] | 0″.759 | 4.3 | A | 3″.66 | 14.2 | −13.7 |
| −1.6 | Sirius = Alpha (α) of Canis Major | .376 | 8.7 | A | 1″.32 | 10.3 | −5. |
| 3.7 | Tau (τ) of Cetus | .334 | 9.8 | B | 1″.93 | 17.0 | |
| 0.5 | Procyon = Alpha (α) of Canis Minor | .324 | 10.1 | B | 1″.25 | 11.3 | −2.5 |
| 5.6 | *61* of Cygnus | .311 | 10.5 | A | 5″.25 | 49.6 | −39. |
| 0.9 | Altair = Alpha (α) of Aquila | .238 | 13.7 | B | .65 | 8.0 | −20.5 |
| 3.6 | Eta (η) of Cassiopeia | .201 | 16.2 | B | 1″.25 | 18.2 | +5.6 |
| 3.6 | Xi (ξ) of Ursa Major | .179 | 18.2 | C | .73 | 12.0 | |
| 4.5 | Omicron ($o^2$) of Eridanus | .174 | 18.8 | B | 4″.08 | 69.0 | |
| 3.0 | Zeta (ζ) of Hercules | .142 | 22.9 | B | .61 | 12.6 | |
| V | Mira = Omicron (o) of Cetus | .142 | 22.9 | B | .23 | 4.7 | +40.4 |
| 1.3 | Fomalhaut = Alpha (α) of Piscis Austrinus | .138 | 23.6 | B | .37 | 7.9 | |
| 2.2 | Denebola = Beta (β) of Leo | .129 | 25.3 | C | .51 | 11.6 | |
| 3.8 | Beta (β) of Virgo | .118 | 27.6 | C | .79 | 19.6 | +2.5 |
| 5.3 | Mu (μ) of Cassiopeia | .112 | 29.1 | B | 3″.75 | 98.2 | −60.3 |
| 2.4 | Gamma (γ) of Draco | .107 | 30.5 | C | .025 | 0.7 | −16.8 |
| 3.5 | Mu (μ) of Hercules | .106 | 30.8 | C | .813 | 22.5 | −9.3 |
| 2.3 | Gamma (γ) of Cygnus | .106 | 30.8 | C | .003 | 0.08 | −4.4 |
| 0.1 | Vega = Alpha (α) of Lyra | .094 | 34.7 | B | .35 | 10.9 | −9.3 |
| 3.3 | Theta (θ) of Ursa Major | .092 | 35.5 | C | 1″.09 | 34.8 | +9.3 |
| 0.2 | Arcturus = Alpha (α) of Boötes | .075 | 43.5 | A | 2″.28 | 89.3 | −3.1 |
| 2.4 | Beta (β) of Cassiopeia | .074 | 44.1 | B | .56 | 22.2 | |
| 2.1 | Ras Alhague = Alpha (α) of Ophiuchus | .074 | 44.1 | B | .26 | 10.3 | |
| 1.1 | Aldebaran = Alpha (α) of Taurus | .073 | 44.7 | B | .20 | 8.0 | +34.2 |
| 0.2 | Capella = Alpha (α) of Auriga | .066 | 49.4 | B | .44 | 19.6 | +18.6 |
| 1.2 | Pollux = Beta (β) of Gemini | .064 | 50.9 | B | .62 | 28.4 | +1.9 |
| 2.9 | Gamma (γ) of Virgo | .058 | 56.2 | B | .55 | 27.8 | −13.1 |
| 1.1 | [Alpha (α) of Crux] | .055 | 59.3 | B | .06 | 3.2 | |
| 0.6 | [Achernar = Alpha (α) of Eridanus] | .051 | 64.0 | B | .09 | 5.2 | |
| 2.1 | Polaris = Alpha (α) of Ursa Minor | .047 | 69.4 | B | .04 | 2.5 | |
| 0.9 | [Beta (β) of Centaurus] | .037 | 88.1 | B | .04 | 3.2 | |
| 1.3 | Regulus = Alpha (α) of Leo | .033 | 99 | B | .25 | 22.2 | |
| 2.2 | Mizar = Zeta (ζ) of Ursa Major | .033 | 99 | A | .13 | 11.5 | −8.1 |
| V | Betelgeuze = Alpha (α) of Orion | .030 | 109 | B | .03 | 2.9 | |
| 1.2 | Antares = Alpha (α) of Scorpius | .029 | 112 | B | .03 | 3.0 | −1.9 |
| 1.6 | Castor = Alpha ($\alpha^2$) of Gemini | .028 | 116 | B | .20 | 20.9 | +3.7 |
| 1.5 | [Beta (β) of Crux] | .008 | 408 | B | .06 | 22.0 | |
| 2.2 | Alamak = Gamma (γ) of Andromeda | .007 | 466 | B | .07 | 29.4 | −6.8 |
| 0.3 | Rigel = Beta (β) of Orion | .007 | 466 | B | .00 | 0. | |
| −0.9 | [Canopus = Alpha (α) of Carina (Argo Navis)] | .007 | 466 | B | .02 | 8.4 | +12.4 |
| 1.7 | Bellatrix = Gamma (γ) of Orion | −.003 | 500+ | A | .02 | | |
| 1.3 | Deneb = Alpha (α) of Cygnus | −.004 | 500+ | A | .004 | | |
| 1.2 | Spica = Alpha (α) of Virgo | −.012 | 500+ | A | .05 | | +1.2 |
| 3.1 | Albireo = Beta (β) of Cygnus | −.021 | 500+ | A | .01 | | −14.9 |
| 7.6 | Lalande 21, 185 (R. A. Xh. 57.9m.; D. +36° 38′) | .403 | 8.1 | A | 4.77 | 34.9 | |
| 8.2 | Groombridge 34 (R. A. Oh. 12.5m.; D. +43° 27′) | .281 | 11.6 | A | 2.85 | 29.8 | |
| 8.9 | Lalande 21, 258 (R. A. XIh. 0.5m.; D. +44° 2′) | .203 | 16.1 | B | 4.46 | 64.8 | |
| 6.5 | Groombridge 1830 (R. A. XIh. 47.2m.; D. +38° 26′) | .102 | 32.0 | B | 7.07 | 204.3 | −58.9 |

A list is here given of the seventy brightest stars, indicating their magnitudes according to the Revised Harvard Photometry (1908) in the column marked H; and according to the determinations of the Astrophysical Observatory, Potsdam, in the column marked P, as shown in the *Sternverzeichnis* of Ambronn, 1907. In both H and P the figure is here

TABLE B. STAR MAGNITUDES

| No. | Star | H | P | B |
|---|---|---|---|---|
| 1 | Sirius = Alpha (α) of Canis Major | —1.6 | | 10.76 |
| 2 | [Canopus = Alpha (α) of Carina] | —0.9 | | 5.75 |
| 3 | [Alpha (α) of Centaurus] | 0.1 | | 2.29 |
| 4 | Vega = Alpha (α) of Lyra | 0.1 | 0.4 | 2.29 |
| 5 | Capella = Alpha (α) of Auriga | 0.2 | 0.5 | 2.09 |
| 6 | Arcturus = Alpha (α) of Boötes | 0.2 | 0.3 | 2.09 |
| 7 | Rigel = Beta (β) of Orion | 0.3 | | 1.91 |
| 8 | Procyon = Alpha (α) of Canis Minor | 0.5 | 0.8 | 1.59 |
| 9 | [Achernar = Alpha (α) of Eridanus] | 0.6 | | 1.44 |
| 10 | [Beta (β) of Centaurus] | 0.9 | | 1.10 |
| 11 | Altair = Alpha (α) of Aquila | 0.9 | 1.2 | 1.10 |
| 12 | Betelgeuze = Alpha (α) of Orion, *max* | 0.9 | | 1.10 |
| 13 | [Alpha (α) of Crux] | 1.1 | | 0.91 |
| 14 | Aldebaran = Alpha (α) of Taurus | 1.1 | 1.2 | 0.91 |
| 15 | Pollux = Beta (β) of Gemini | 1.2 | 1.5 | 0.83 |
| 16 | Spica = Alpha (α) of Virgo | 1.2 | | 0.83 |
| 17 | Antares = Alpha (α) of Scorpius | 1.2 | | 0.83 |
| 18 | Fomalhaut = Alpha (α) of Piscis Austrinus | 1.3 | | 0.76 |
| 19 | Deneb = Alpha (α) of Cygnus | 1.3 | 1.6 | 0.76 |
| 20 | Regulus = Alpha (α) of Leo | 1.3 | 1.8 | 0.76 |
| 21 | [Beta (β) of Crux] | 1.5 | | 0.63 |
| 22 | Castor = Alpha (α) of Gemini | 1.6 | 2.0 | 0.58 |
| 23 | [Gamma (γ) of Crux] | 1.6 | | 0.58 |
| 24 | Epsilon (ε) of Canis Major | 1.6 | | 0.58 |
| 25 | Alioth = Epsilon (ε) of Ursa Major | 1.7 | 2.2 | 0.52 |
| 26 | Bellatrix = Gamma (γ) of Orion | 1.7 | 2.1 | 0.52 |
| 27 | Lefath = Lambda (λ) of Scorpius | 1.7 | | 0.52 |
| 28 | [Epsilon (ε) of Carina] | 1.7 | | 0.52 |
| 29 | Alnilam = Epsilon (ε) of Orion | 1.8 | | 0.48 |
| 30 | Nath = Beta (β) of Taurus | 1.8 | 2.0 | 0.48 |
| 31 | [Beta (β) of Carina] | 1.8 | | 0.48 |
| 32 | [Alpha (α) of Triangulum Australe] | 1.9 | | 0.44 |
| 33 | Algenib = Alpha (α) of Perseus | 1.9 | 2.2 | 0.44 |
| 34 | Benetnasch = Eta (η) of Ursa Major | 1.9 | 2.3 | 0.44 |
| 35 | Zeta (ζ) of Orion | 1.9 | | 0.44 |
| 36 | Alhena = Gamma (γ) of Gemini | 1.9 | 2.3 | 0.44 |
| 37 | Dubhe = Alpha (α) of Ursa Major | 2.0 | 2.0 | 0.40 |
| 38 | Epsilon (ε) of Sagittarius | 2.0 | | 0.40 |
| 39 | Wezen = Delta (δ) of Canis Major | 2.0 | | 0.40 |
| 40 | Beta (β) of Canis Major | 2.0 | | 0.40 |
| 41 | [Delta (δ) of Vela] | 2.0 | | 0.40 |
| 42 | Theta (θ) of Scorpius | 2.0 | | 0.40 |
| 43 | Menkalinan = Beta (β) of Auriga | 2.1 | 2.2 | 0.36 |
| 44 | Polaris = Alpha (α) of Ursa Minor | 2.1 | 2.3 | 0.36 |
| 45 | [Alpha (α) of Pavo] | 2.1 | | 0.36 |
| 46 | Ras Alhague = Alpha (α) of Ophiuchus | 2.1 | 2.5 | 0.36 |
| 47 | Sigma (σ) of Sagittarius | 2.1 | | 0.36 |
| 48 | Algol = Beta (β) of Perseus, *max* | 2.1 | 2.3 | 0.36 |
| 49 | Alpheratz = Alpha (α) of Andromeda | 2.2 | 2.4 | 0.33 |
| 50 | [Alpha (α) of Grus] | 2.2 | | 0.33 |
| 51 | Alphard = Alpha (α) of Hydra | 2.2 | 2.2 | 0.33 |
| 52 | Mizar = Zeta (ζ) of Ursa Major | 2.2 | 2.4 | 0.33 |
| 53 | Saiph = Kappa (κ) of Orion. | 2.2 | | 0.33 |
| 54 | Alamak = Gamma (γ) of Andromeda | 2.2 | 2.4 | 0.33 |
| 55 | [Lambda (λ) of Vela] | 2.2 | | 0.33 |
| 56 | [Gamma (γ) of Vela] | 2.2 | | 0.33 |
| 57 | Denebola = Beta (β) of Leo | 2.2 | 2.6 | 0.33 |
| 58 | Hamal = Alpha (α) of Aries | 2.2 | 2.2 | 0.33 |
| 59 | Deneb Kaitos = Beta (β) of Cetus | 2.2 | | 0.33 |
| 60 | Kochab = Beta (β) of Ursa Minor | 2.2 | 2.3 | 0.33 |
| 61 | [Beta (β) of Grus] | 2.2 | | 0.33 |
| 62 | Alpha (α) of Cassiopeia, *max.* | 2.2 | 2.3 | 0.33 |
| 63 | [Iota (ι) of Carina] | 2.3 | | 0.30 |
| 64 | Gamma (γ) of Cassiopeia | 2.3 | 2.5 | 0.30 |
| 65 | [Theta (θ) of Centaurus] | 2.3 | | 0.30 |
| 66 | [Zeta (ζ) of Puppis] | 2.3 | | 0.30 |
| 67 | Gemma = Alpha (α) of Corona Borealis | 2.3 | 2.6 | 0.30 |
| 68 | Gamma (γ) of Cygnus | 2.3 | 2.5 | 0.30 |
| 69 | Epsilon (ε) of Scorpius | 2.4 | | 0.28 |
| 70 | Mirach = Beta (β) of Andromeda | 2.4 | 2.3 | 0.28 |

carried to only one decimal, fractions over .05 counting as .1. For example, the precise mag. of Sirius is −1.58. Stars south of the celestial equator were not included in the Potsdam determinations.

In the column marked B is indicated the relative brilliancy of a number of the stars on a simple decimal scale, assuming Aldebaran—the Alpha ($\alpha$) of Taurus—as approximately a first-magnitude star. No star is precisely of mag. 1.0. By this method it may be seen at a glance that Sirius is more than 10 times as bright as a standard first-magnitude, that Capella is more than twice as bright as such a star, and that Epsilon ($\varepsilon$) in Ursa Major, the third star from the tip in the Dipper's handle, is about half as bright. These decimal notations are based on the magnitudes as shown in column H.

The system of notation just described is far simpler than the comparison of stars by "magnitudes," for in the scale of magnitudes the beginner is confused by the occurrence of zero magnitudes and negative (= minus) magnitudes, these notations applying to some of the brightest and most interesting stars. A 2d-magnitude star is about 2.51 times fainter than a first-magnitude, a 3d-mag. star is about 2.51 times fainter than a 2d-magnitude, etc. The scale, even in this direction, is confusing, because the brilliancy of the star does not increase with the increase of the numeral of magnitude, but the reverse. Yet in the other direction the conventional scale becomes still more troublesome, for as Aldebaran and Altair are approximately of the first magnitude, there is no way to indicate stars brighter than these, except by resorting to decimals of unity. We have been forced, therefore, to describe Vega as mag. 0.1, Arcturus as mag. 0.2, and Sirius as lower in magnitude than zero, or of mag. minus, − 1.6. And this is the *brightest* star in the sky! Among the technicalities of a really noble science this system is, in the judgment of the plain man, one of the "puzzles" of astronomy. As current text-books and monographs all assume the traditional photometric scale, the maps, etc., of this book have been composed in accordance with it. The beginner will find that the slight variations between the Harvard and Potsdam results are chiefly due to the factor of *color* in the light of the stars. The Harvard results are usually accepted as standard in England and the United States. The first twenty of the seventy stars in the column marked H are generally classified as of the "first magnitude"; the remaining fifty, with some ten others, are of the "second magnitude."

We have seen that the individual stars are often designated by the Greek letter, used with the Latin *genitive* of the constellation name; see p. 12, second footnote. For readers who do not know Latin, some of these genitive forms that are less easily recognized are here given in italics:—Aries, *Ariētis;* Cancer, *Cancri;* Cētus, *Cētī;* Cygnus, *Cygni;* Draco, *Dracōnis;* Gemini, *Geminōrum;* Leo, *Leōnis;* Lepus, *Lepŏris;* Libra, *Librae;* Orion, *Oriōnis;* Perseus, *Persei;* Serpens, *Serpentis;* Taurus, *Tauri;* Ursa Major, *Ursae Majōris;* Virgo, *Vírginis.*

## Some Variable Stars

Many of the stars show marked changes in brilliancy, *varying* in magnitude. These variations are in many cases periodic, and in some instances we have been able to ascertain the causes of change; see p. 13. In other cases no adequate explanation of these changes in brightness has been found. A few of the best known are given in this list. Those marked S. B. are also spectroscopic binaries, their periods of variation corresponding to their periods of revolution. This may indicate that at minimum one component (as the stars revolve round their common centre of gravity) passes behind the other and is totally or partially eclipsed. The magnitude of each variable star at its maximum and at its minimum is indicated in the table below; and, in the column marked P, is indicated the

period of variability in *Days*. The smaller variables are usually given, for symbols, the Arabic capitals in the order of their discovery in each constellation,—as *R Leporis*. For this use of the Latin genitive, see p. 141; also see second footnote on p. 12.

TABLE C. SOME WELL-KNOWN VARIABLES

| Star | Max. | Min. | P. | Star | Max. | Min. | P. |
|---|---|---|---|---|---|---|---|
| Eta (η) of Aquila (S. B.) | 3.7 | 4.5 | 7.18 | Ras Algethi = Alpha (α) of Hercules | 3.1 | 3.9 | |
| [Eta (η) of Argo (Carina)] | 1. | 7.4 | | R of Lepus | 6.1 | 9.7 | 436.1 |
| Epsilon (ε) of Auriga (S. B.) | 3.4 | 4.1 | 9905. | Delta (δ) of Libra (S. B.) | 4.8 | 6.2 | 2.33 |
| Alpha (α) of Cassiopeia | 2.2 | 2.8 | | Iota (ι) of Libra | 4.3 | 5. | |
| Delta (δ) of Cepheus (S. B.) | 3.7 | 4.6 | 5.37 | Sheliak = Beta (β) of Lyra (S. B.) | 3.4 | 4.1 | 12.9 |
| Mu (μ) of Cepheus | 4.? | 5.? | | Betelgeuze = Alpha (α) of Orion | 0.9 | 1.4 | |
| Mira = Omicron (o) of Cetus | 1.7 | 9.6 | 331.6 | Algol = Beta (β) of Perseus (S. B.) | 2.1 | 3.2 | 2.87 |
| Chi (χ) of Cygnus | 4. | 13.5 | 406. | Rho (ρ) of Perseus | 3.4 | 4.2 | |
| Eta (η) of Gemini (S. B.) | 3.2 | 4.2 | 231.4 | Lambda (λ) of Taurus (S. B.) | 3.3 | 4.2 | 4. |
| Zeta (ζ) of Gemini (S. B.) | 3.7 | 4.3 | 10.15 | | | | |

## SOME BINARY SYSTEMS

As already explained, pp. 12 and 117, many of the double stars represent two suns in revolution about a common centre of gravity. In some cases their orbits have been calculated, and the periods of revolution are known with a fair degree of accuracy. In this table, the combined magnitude of the components is indicated in the column marked Mag.; the individual mag. of the components in the col. marked M. of Comp., and their period of revolution, in *Years*, is shown in the col. marked P. At the close of the table are added a few important binaries with long periods. The longer the period, the larger the probability of error. In some cases, like that of Gamma (γ) of Leo, the period is so long and so uncertain that it has seemed best not to include them here.

TABLE D. TELESCOPIC BINARIES

| Mag. | Star | P. | M. of Comp. | Mag. | Star | P. | M. of Comp. |
|---|---|---|---|---|---|---|---|
| 4.3 | Kappa (κ) of Pegasus | 11.4 | 4.3, 5.5 | 3.9 | Xi (ξ) of Ursa Major | 60. | 4.4, 4.9 |
| 3.5 | Epsilon (ε) of Hydra | 15.7 | 3.5, 6.7 | 3.9 | Gamma (γ) of Corona Borealis | 73. | 4.0, 7 |
| 3.7 | Beta (β) of Delphinus | 27.7 | 4.0, 6.1 | 0.1 | Alpha (α) of Centaurus | 81.2 | 0.3, 1.7 |
| 3.0 | Zeta (ζ) of Hercules | 34.5 | 3.2, 6.5 | 4.1 | 70 of Ophiuchus | 88.4 | 4.3, 6 |
| 5.0 | Eta (η) of Corona Borealis | 41.5 | 5.6, 6.1 | 4.6 | Xi (ξ) of Boötes | 148.5 | 4.8, 6.8 |
| 4.2 | Xi (ξ) of Scorpius | 44.5 | 4.8, 5.1 | 4.5 | Omicron ($o^2$) of Eridanus | 180.0 | 4.5, 9.1 |
| −1.6 | Sirius = Alpha (α) of Canis Major | 48.8 | −1.6, 8.4 | 2.9 | Gamma (γ) of Virgo | 194.0 | 3.7, 3.7 |
| 2.2 | Alamak = Gamma (γ) of Andromeda | 55. | 2.3, 5.1 | 4.3 | Mu ($\mu^2$) of Boötes | 275.8 | 4.5, 6.7 |
| 3.8 | Tau (τ) of Cygnus | 57.3 | 4.0, 8 | 3.6 | Eta (η) of Cassiopeia | 327.9 | 3.7, 7.6 |
| 4.7 | Zeta (ζ) of Cancer | 59.1 | 5.0, 5.7 | 1.6 | Castor = Alpha (α) of Gemini | 346.8 | 2.0, 2.9 |

These are binary systems discovered by means of the spectroscope, the component suns being so near together that it has been impossible to effect their division with the telescope; see p. 117. The periods of revolution are indicated in *Days* in the col. marked D. At the close of the table I have listed a number of important stars thought to be spectroscopic binaries but the *periods* of which have not yet (1912) been determined.

A Few Spectroscopic Binaries. Table E

| Mag. | Star | Period in Days. | Mag. | Star | Period in Days. |
|---|---|---|---|---|---|
| 2.2 | Alpheratz = Alpha (α) of Andromeda | 96.7 | 2.5 | Mintaka = Delta (δ) of Orion | 5.73 |
| 3.4 | Theta (θ) of Aquila | 17.12 | 2.9 | Iota (ι) of Orion | 29.14 |
| V | Eta (η) of Aquila | 7.18 | V | Algol = Beta (β) of Perseus | 2.87 |
| 2.7 | Beta (β) of Aries | 107.0 | 1.2 | Antares = Alpha (α) of Scorpius | 2120. |
| 0.2 | Capella = Alpha (α) of Auriga | 104. | 3.0 | Zeta (ζ) of Taurus | 138. |
| 2.1 | Beta (β) of Auriga | 3.96 | 2.4 | Merak = Beta (β) of Ursa Major | 27.16 |
| 3.3 | Beta (β) of Capricornus | 1375. | 2.2 | Mizar = Zeta (ζ) of Ursa Major | 20.54 |
| −0.9 | Canopus = Alpha (α) of Carina | 6.74 | 2.1 | Polaris = Alpha (α) of Ursa Minor | 3.97 |
| 3.3 | Alphirk = Beta (β) of Cepheus | 0.19 | 1.2 | Spica = Alpha (α) of Virgo | 4.01 |
| V | Delta (δ) of Cepheus | 5.37 | 1.7 | Lefath = Lambda (λ) of Scorpius | 5.6 |
| 2.3 | Gemma = Alpha (α) of Corona Borealis | 17.36 | 2.0 | Beta (β) of Canis Major | 0.25 |
| 3.6 | Thuban = Alpha (α) of Draco | 51.38 | V | Betelgeuze = Alpha (α) of Orion | |
| 2.9 | Castor = Alpha ($\alpha^1$) of Gemini | 2.93 | 1.3 | Deneb = Alpha (α) of Cygnus | |
| 2.0 | Alpha ($\alpha^2$) of Gemini | 9.22 | 1.7 | Alioth = Epsilon (ε) of Ursa Major | |
| V | Mekbuda = Zeta (ζ) of Gemini | 10.15 | 1.7 | Bellatrix = Gamma (γ) of Orion | |
| 2.8 | Beta (β) of Hercules | 410.6 | 1.8 | Alnilam = Epsilon (ε) of Orion | |
| 3.9 | Epsilon (ε) of Hercules | 4.01 | 1.9 | Algenib = Alpha (α) of Perseus | |
| V | Delta (δ) of Libra | 2.33 | 1.9 | Gamma (γ) of Gemini | |
| V | Sheliak = Beta (β) of Lyra | 12.91 | 2.0 | Dubhe = Alpha (α) of Ursa Major | |
| 0.3 | Rigel = Beta (β) of Orion | 21.9 | 5.6 | $61^1$ and $62^2$ of Cygnus | |
| | | | 4. | Alcor (*g*) of Ursa Major | |

## Useful Work for the Amateur

Facing the preface of this book are two quotations from Dr. George E. Hale of the Mt. Wilson Solar Observatory, in reference to the useful work which may be accomplished by the amateur. Dr. Hale has special reference to the spectroscope. So broad, however, is his suggestion that it is quite as applicable to the telescope. Indeed it is usually through the elementary preparation afforded by the telescope that the beginner advances to the use of the spectroscope itself.

The amateur observer who may wish to attempt some useful work, may take up: (1) the study of variable stars; or (2) the careful systematic search for comets; or (3) the observation of the surface markings of the planets; or (4) the study of double stars; or (5) the drawing and recording of sun-spots; or (6) the making of careful records as to meteors and meteor trails, or other unusual phenomena that may come under observation. Records

made *at the time* are often of special value. Fully to deal with these various interests would require the preparation of another volume.

One of the most fruitful fields for amateur effort is the first named—that of variable stars. After becoming fairly familiar with the constellations and with the ordinary use of the telescope, the amateur who wishes to aid in the observation of variables should enter into correspondence with a working observatory. That of Harvard College, Cambridge, Mass., is one of a number of institutions giving direction to amateurs in the study of variables. Letters addressed simply to the "Director" of the Observatory will be referred by him to the proper secretary.

Reference has already been made to the search for comets. In such work, one must be in patience persistent and in persistence patient! But any amateur who *regularly* sweeps with his telescope any definitely selected portion of the sky at intervals of a few days is not unlikely to be rewarded by the finding of a comet. First, however, he should learn what the smaller comets look like, and how they behave, by following some of those which are frequently reported in the astronomical journals. Upon finding a comet, the fact, with the approximate position of the object in R. A. and D. (see note 14, p. 32), should be at once communicated, for verification, to an observatory.

As to double-stars, the contrasts of color may usually be studied with greater accuracy in a reflector than in a refractor, and yet even such small refractors as are noted in this book may prove useful. The focal length of the objective should, however, be long enough for great refinement of definition, and the eyepieces should be carefully corrected for color. Cheaper instruments may not show colors so accurately, but they may aid the eye in learning to estimate the magnitudes of the telescopic components of the easier doubles. First make a list of the doubles to be observed, trying not to note the magnitudes of the companion stars. Then observe, and record your estimates of the magnitudes of both components, and afterward compare your estimates with the magnitudes as given in the Observer's Catalogue. This will gradually provide a *training* to the eye in estimating the magnitudes of *telescopic* objects, a training highly serviceable in the study of variables.

It is chiefly important to remember that any work that interests the observer and which he is willing to do deliberately and carefully is likely to be of ultimate service to science. No matter how "useless" it may be called, such labor must result in the education of the amateur in habits of observation,—in accuracy, precision, and mental force. As these capacities increase, new interests and opportunities will open out. Things that are worth doing are frequently brought to the observer's attention in the pages of our popular astronomical periodicals. A journal like *Popular Astronomy*, noted on p. 146, is often most helpful with suggestions.

## A List of Books

Whether or not the beginner desires to give interest and time to scientific work, there will be the need for further information. This volume has not attempted to fill the place of a text-book on astronomy, and therefore the questions of *how* and *why* will demand further attention. Fuller and more technical manuals for the telescope will also be desirable, as well as a star-atlas and a planisphere. A few volumes on the general history of astronomy and on special subjects may be added, according to the need or interest of the student.

Some of the best of the general text-books are: (1) *A Popular Astronomy*, by the late Simon Newcomb, Director of the U. S. Naval Observatory, Washington; American Book Co., N. York. Not kept up to date as to recent developments but peculiarly able and

lucid in its expositions.[1] (2) *Elementary Lessons in Astronomy*, by Sir Norman Lockyer; London, Macmillan & Co. Clearly and vividly written. (3) *A New Astronomy*, by Prof. David Todd; the American Book Co., N. York. Rich in illustrative experiments. (4) *The Family of the Sun*, by E. S. Holden; published by D. Appleton & Co., N. York and London. (5) *Descriptive Astronomy;* by H. A. Howe, Director of the Chamberlin Obs.; Silver, Burdett & Co., Boston and N. York. (6) *A Manual of Astronomy*, by the late C. A. Young, of Princeton University; Ginn & Co., N. York and Boston. A little difficult for the beginner, but a thoroughly well-wrought book,—perhaps the best general statement of the whole subject available at this time (1912) in English.

Among the simpler volumes, of value in learning the constellations, may be mentioned: (1) *A Field Book of the Stars*, by William Tyler Olcott; G. P. Putnam's Sons, N. York & London; (2) *Astronomy with an Opera-Glass*, by Garrett P. Serviss; D. Appleton & Co., N. York; (3) *Half-Hours with the Stars*, by R. A. Proctor; G. P. Putnam's Sons, N. York and London; (4) Flammarion's *Astronomy for Amateurs;* English translation pub. by D. Appleton & Co., N. York. An admirable first-book in its field is *The Spectroscope and its Work*, by H. F. Newall, M.A., Prof. of Astrophysics in the University of Cambridge, England; pub. by the S. P. C. K., London, and by E. Gorham, N. York.

Among the more satisfactory star atlases are: (1) the *Stern Atlas* of J. Messer, pub. by K. L. Ricker, Leipzig; to be had of G. E. Stechert & Co., N. York and London. The two maps at the close of this volume were suggested by Messer's final plates, but they have been entirely redrawn by hand, the scale reduced, and the star magnitudes brought into harmony with the latest determinations. (2) The *Himmel Atlas* of Schurig, new edition 1910, is less expensive—costing less than $1.00—and is attractive and adequate. There is so little text to Schurig's *Atlas* that translation is hardly necessary. (3) The *Star Atlas* of Klein is supplied with full descriptions of telescopic objects. These are translated by McClure for the English edition, of which the Society for Promoting Christian Knowledge is publisher, New York and London. (4) The *New Star Atlas*, by R. A. Proctor, is supplied with no descriptive matter, but it is small in size as well as convenient and accurate; Longmans Green & Co., N. York and London. (5) *A Popular Guide to the Heavens*, by Sir Robert Ball, contains a star atlas as well as an atlas of the moon, together with much illustrative material; more expensive than any of the preceding. Pub. by Philip & Son, London, and the D. Van Nostrand Co., N. York.

Among books especially written for larger instruments I would heartily commend: (1) *Celestial Objects for Common Telescopes*, by the Rev. T. W. Webb, F.R.A.S.; Longmans Green & Co., N. York and London. The beginner, just at the first, will find it too full for his uses, but it will soon prove indispensable. It covers the subjects of Sun, moon, planets, etc., as well as the stars. Webb's map of the moon is especially clear and full. A very satisfactory map of the moon will also be found in *The Moon*, by T. G. Elger; pub. by Philip, London; and the D. Van Nostrand Co., N. York. (2) On the stars, star-clusters, nebulæ, etc.,—but not the objects of the solar system,—see also, the *Cycle of Celestial Objects*, by Smyth and Chambers; The Oxford Press, N. York and London. In addition

[1] Its high qualities were early recognized in Germany, where the volume was translated by Engelmann, and has been successively edited and enlarged by Vogel and Kempf of the Royal Observatory, Potsdam, and certain associates of the highest standing. This German volume, known as the *Populäre Astronomie* of *Newcomb-Engelmann* is now (1912) in its fourth edition. It is three or four times the size of Newcomb's original book, and fully illustrated. Despite some defects, it is on the whole the very best exposition and exhibit of the present state of astronomical science —admirable in itself, and a generous tribute to America's greatest astronomer. I am largely indebted to this volume for the material in the table of Spectroscopic Binaries here given. To be had, as yet, only in German; of G. E. Stechert & Co., N. Y. and London. Published by W. Engelmann, Leipzig.

to my many obligations to the books named above, I would also mention an admirable volume by James Baikie, F.R.A.S., called *Through the Telescope;* pub. by A. and C. Black, London. Fowler's *Popular Telescopic Astronomy;* T. Whittaker, N. York; the *Amateur Telescopist's Handbook*, by F. M. Gibson, and Noble's *Hours with a Three-inch Telescope;* the last two pub. by Longmans, may also be mentioned here. I have expressed my chief acknowledgments in the preface to the present volume. Among the best general books on the subject for the serious modern reader are the volumes by the late Miss Agnes M. Clerke —*The System of the Stars*, second edition much revised; and the *History of Astronomy in the Nineteenth Century*, and *Problems in Astrophysics*,—all pub. by A. & C. Black. In scholarship and in general intellectual power Miss Clerke has taken rank among the leading women of the nineteenth century. On the poetry and mythology of the stars there is a charming and inexpensive little volume by Dr. J. G. Porter, *The Stars in Song and Legend*, with illustrations from the drawings of Albrecht Dürer; pub. by Ginn & Co., N. York and London. The national *Ephemeris* is indispensable; see footnote on page 82.

The beginner should early learn to use all his authorities with discrimination. The literature of astronomy abounds in detail; error is therefore inevitable. Prof. Young, of Princeton University, praised astronomy as a training in accuracy, yet obvious inaccuracies appear in his own books—and Prof. Young's books are as accurate as any that exist. No atlas more accurate than Klein's is published, yet the star Delta ($\delta$) in the well-known Dipper is given the fourth magnitude in Plate I, and the third magnitude in Plates III and IV. Schurig's useful atlas, among other errors, marks the great nebula of Andromeda as M. 31 in Tab. III, and as 33 in Tab. I. The latter is the Flamsteed number, but inconsistent usage leads to much confusion. Many errors also arise from the fact that new information has made old figures, or old tables, obsolete. It is therefore important to note the *date* of the book consulted as well as to note the nature of the authorities quoted. That absolute freedom from error has been attained in the present volume the author cannot hope,—though all possible care has been exercised. I can only say that such errors as may be pointed out to me will be promptly and gratefully corrected in future editions.

One or two good astronomical journals will be found useful,—such as *The Observatory*, published at Greenwich, England; or *Popular Astronomy*, published at Northfield, Minn., U. S. A. Among continental periodicals are *Sirius*, in German, published at Berlin,—G. E. Stechert & Co., N. York and London, through whom may be obtained also the monthly *Bulletin* of the *Société Astronomique de France*.

A *planisphere* is a useful device for quickly showing what stars are above the horizon at any particular hour. Among these are *Philips' Planisphere; Whittaker's Planisphere;* and one called the *Barritt and Serviss Planisphere and Planet Finder*. The last is about $5; the two others are sold at retail at less than $1.00. The present volume, if reference be made to p. 35, will serve—approximately—the purposes of a planisphere, as well as a planet finder (p. 82 fol.), for the evening hours of any year. Moreover, while the telescopic objects are seldom indicated in a planisphere, most of the easier objects are here included. As the Night-Charts are especially intended for the unaided eyes, the merely telescopic clusters and nebulae are usually shown only in the Key-Maps. For determining with greater precision the time of the rising and setting of the stars, a good planisphere is, of course, invaluable.

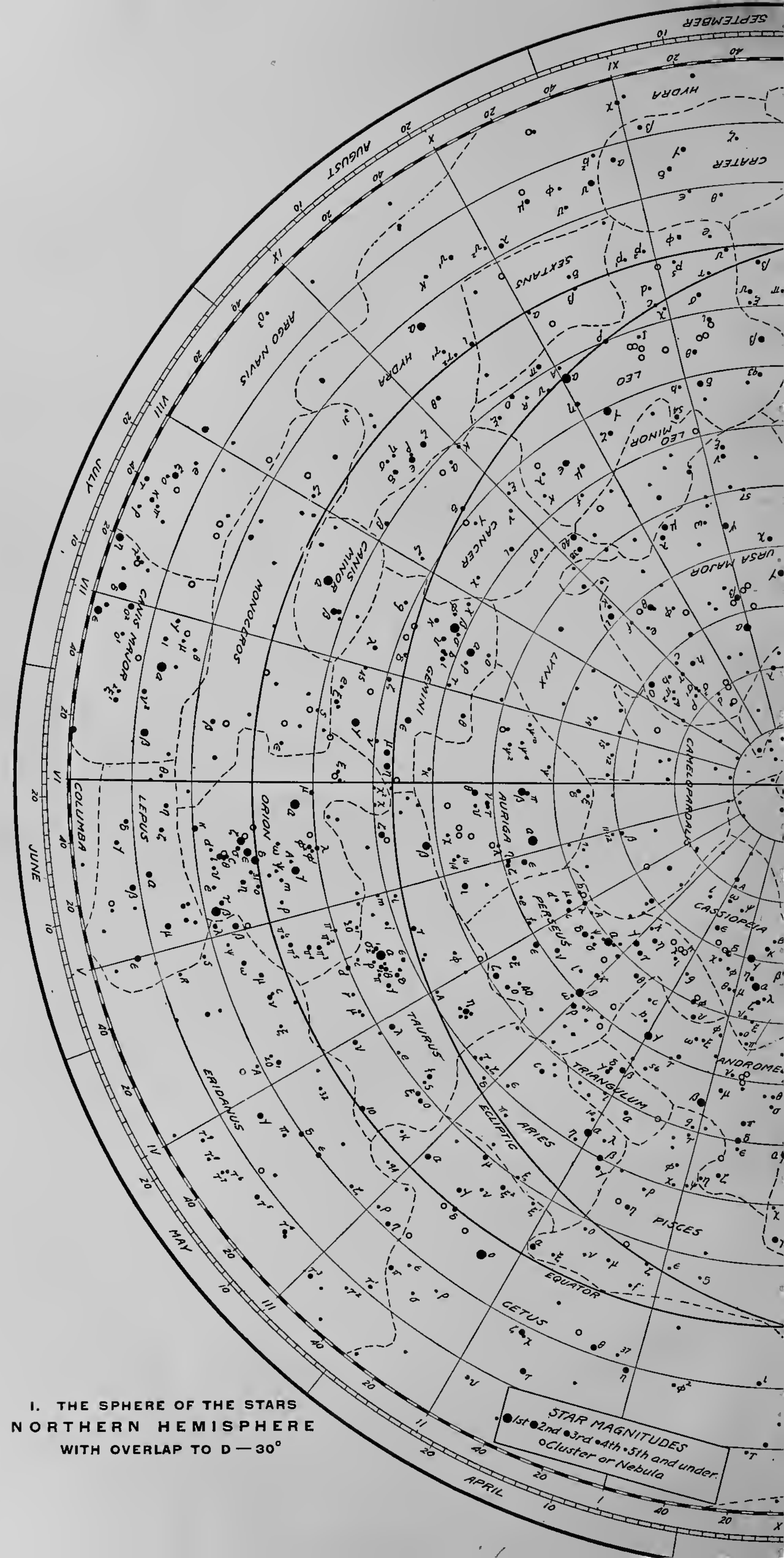
# Index

Names of the Constellations and the brighter stars will be found in the Observer's Catalogue, pp. 116–136, in their alphabetical order, with indication of the maps in which they occur as objects for observation in the evening sky. Use Observer's Catalogue, therefore, as Index for stellar objects.

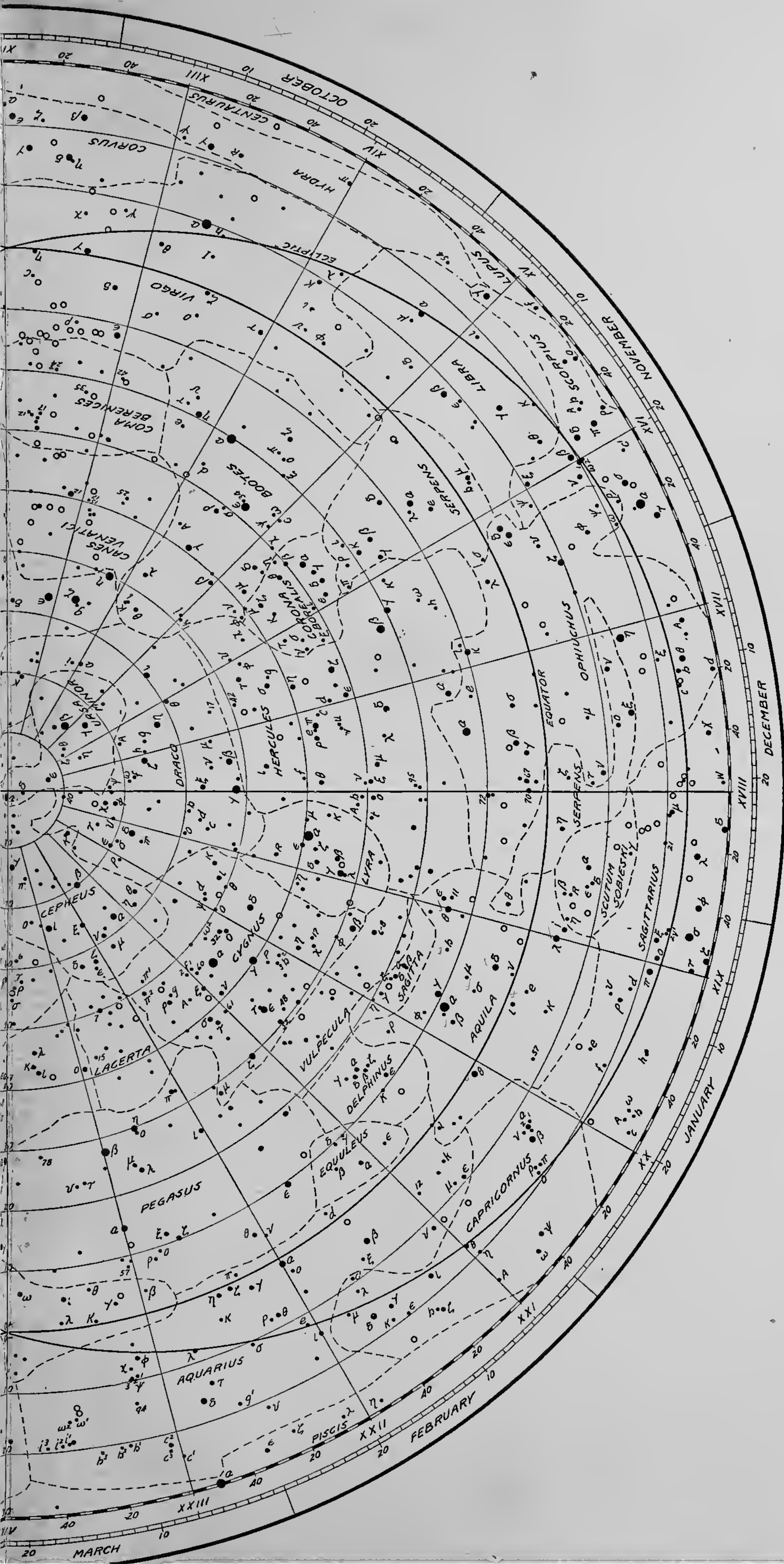
Names of the Planets with tables showing the approximate positions of Venus, Mars, Jupiter, and Saturn for each month will be found on pp. 82, 84, 86 fol.

A Time-Schedule showing the appropriate Night-Charts and Key-Maps for the evening hours of any day in any year will be found on p. 35.

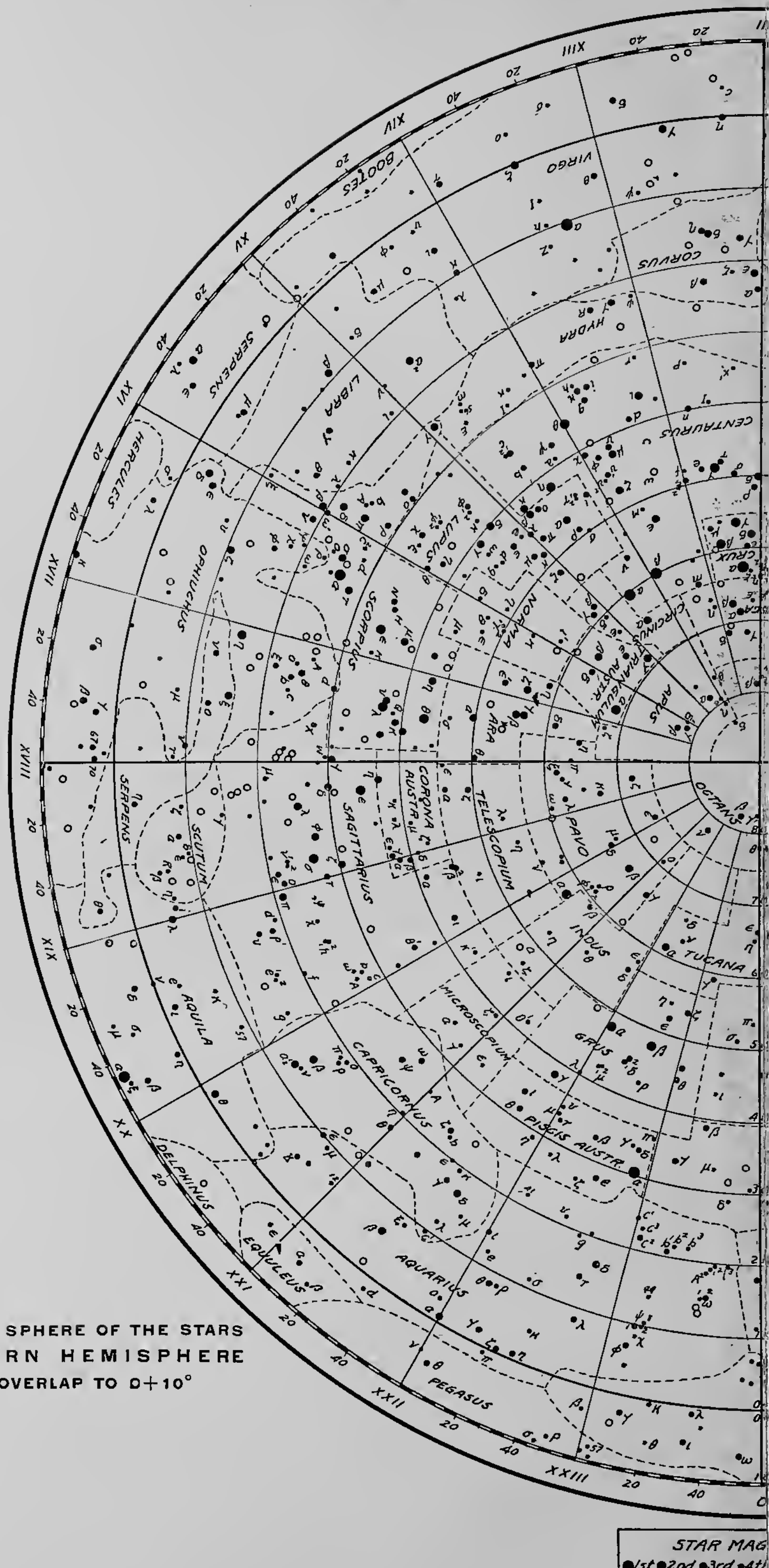
"One might think the atmosphere was made transparent with this design, to give man, in the heavenly bodies, the perpetual presence of the sublime. Seen in the streets of cities how great they are! If the stars should appear one night in a thousand years, how would men believe and adore; and preserve for many generations the remembrance of the city of God which had been shown. . . . We exaggerate the praises of local scenery. In every landscape the point of astonishment is the meeting of the sky and the earth, and that is seen from the first hillock as well as from the top of the Alleghanies. The stars at night stoop down over the brownest, homeliest common, with all the spiritual magnificence which they shed on the Campagna, or on the marble deserts of Egypt. . . . He who knows the most, he who knows what sweets and virtues are in the ground, the waters, the planets, the heavens, and how to come at these enchantments, is the rich and royal man."—R. W. EMERSON; *Nature I; II.*




I. THE SPHERE OF THE STARS
NORTHERN HEMISPHERE
WITH OVERLAP TO D — 30°

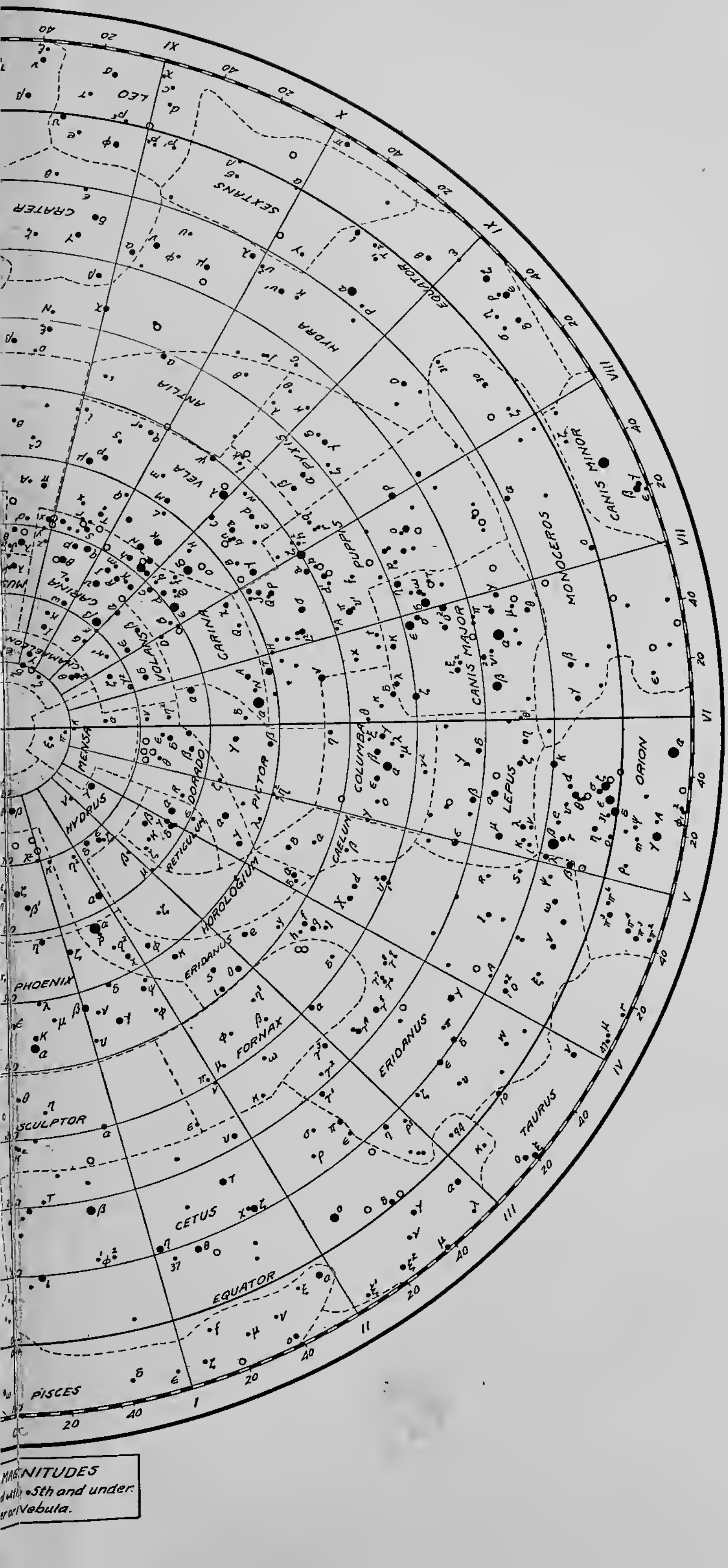

OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
CENTAURUS
CORVUS
HYDRA
ECLIPTIC
LUPUS
VIRGO
SCORPIUS
LIBRA
COMA BERENICES
BOOTES
SERPENS
CANES VENATICI
CORONA BOREALIS
OPHIUCHUS
EQUATOR
URSA MINOR
HERCULES
DRACO
SERPENS
LYRA
SCUTUM SOBIESKI
SAGITTARIUS
CEPHEUS
CYGNUS
SAGITTA
AQUILA
VULPECULA
LACERTA
DELPHINUS
EQUULEUS
CAPRICORNUS
PEGASUS
AQUARIUS
PISCIS

SOUTHERN H




II. THE SPHERE OF THE STARS
SOUTHERN HEMISPHERE
WITH OVERLAP TO D+10°

EMISPHERE


LEO
CRATER
SEXTANS
HYDRA
EQUATOR
ANTLIA
PYXIS
VELA
PUPPIS
CARINA
VOLANS
MONOCEROS
CANIS MINOR
CANIS MAJOR
MENSA
DORADO
PICTOR
COLUMBA
LEPUS
ORION
HYDRUS
RETICULUM
HOROLOGIUM
CAELUM
ERIDANUS
PHOENIX
FORNAX
ERIDANUS
TAURUS
SCULPTOR
CETUS
EQUATOR
PISCES
NITUDES
5th and under.
Nebula.